B.T.

and the

SPRUCE BUDWORM

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Hon. G.S. Merrithew
Minister

R.E. Hanusiak
Deputy Minister

B.T. AND THE SPRUCE BUDWORM - 1983

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Fredericton, New Brunswick on
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J.R. Carrow (Editor)
New Brunswick Department of Natural Resources
P.O. Box 6000
Fredericton, New Brunswick
E3B 5H1

PREFACE

For years, forest managers in eastern Canada have disagreed about the feasibility of using the microbial insecticide B.t. (Bacillus thuringiensis) in spruce budworm spraying programs. This disagreement, which has stemmed from conflicting information, particularly in relation to cost and effectiveness, has been a major obstacle to expanded use of B.t. in New Brunswick. In order to assess the current potential for operational use of B.t., the Department of Natural Resources hosted a seminar on September 8, 1983 in Fredericton. The seminar was designed as an information session for those government and industry staff who are directly involved in planning and carrying out the annual budworm spray program in New Brunswick. Speakers were invited from the jurisdictions which had had operational experience with B.t. since 1980. The following report includes the presentations made by each speaker as well as a summary of information presented.

INTRODUCTION

J.R. Carrow [1]

1983 - over 20 years since Rachel Carson wrote "Silent Spring", a book which attracted wide attention to pesticide use and the potential for environmental damage. In that book, Carson drew public attention to the New Brunswick spruce budworm spraying program by pointing to examples of damage to non-target organisms in the forest ecosystem. Carson's allegations were challenged vigorously by the scientific community, but to many, her story was convincing and frightening. If the book did nothing else, it greatly elevated public awareness and interest in pesticide use - an interest that has persisted for nearly 25 years. In that interval, the public has become more informed and more critical of chemical pesticides, especially in forestry. The fact that criticism has prevailed for so long is a clear sign that public consciousness about environmental quality is here to stay.

While some in the forestry community bemoan the irrational and emotional criticism of forestry use of pesticides, we ignore a very important reality, one that is often more compelling to politicians, senior bureaucrats and corporate executives than scientific or technical arguments. The reality is that, for whatever reason, we do <u>not</u> have broad public support for the use of chemical pesticides in forest management. Indeed the signs are that it will be very difficult to gather public support for intensive forest management, including pesticide use, on publicly-owned lands. Yet New Brunswick is faced with the major challenge of preserving and regulating the harvest of a mature forest which constitutes

[1] N.B. Department of Natural Resources, Fredericton, N.B.

the wood supply for the forest industry until about 2020. The major threat by far to that wood supply is the spruce budworm, and the central issue is whether we will be able to protect that wood supply from budworm until it can be harvested.

The spruce budworm spray program is designed to do just that - preserve the mature forest in a merchantable state until orderly harvesting can take place. Put simply, it is a question of whether we regulate harvesting in New Brunswick, or the spruce budworm.

The New Brunswick spruce budworm spray program has been a focus of criticism for longer than we care to remember, starting with the publication of "Silent Spring". To the man on the street, the program is one which, while it may be necessary, has resulted in the widespread release of chemicals into the environment for over 30 years. Likewise, the program has not evolved much, relying now on synthetic chemicals just as it did 30 years ago, despite persistent expressed concerns about adverse effects. This man on the street is important, because he represents the many sectors of society - the truck driver, the clerk, the lawyer, the merchant and the elected politician - and their opinions ultimately coalesce to shape government policy. Lack of support by the man in the street <u>eventually</u> translates into reduced support for the program.

Criticism of the spray program is directed primarily at the user or the applicator - in New Brunswick, the Department of Natural Resources and the industrial Licensees, as represented by Forest Protection Ltd. Such criticism inevitably leads to increasing restriction on pesticide use <u>or</u> suspension of specific pesticides. Given this situation, the forest manager <u>must</u> have options for protection, if he is to fulfill his management responsibility. Environmental restrictions are a reality in New Brunswick and they are significant

enough to affect major portions of our forest resource. In the small woodlot program alone, 100 000 acres of forest which needed protection in 1983 went unprotected due to restrictions on chemical use. Most of the areas where aerial chemical spraying is not permitted by Environment N.B., represent highly productive sites, in which the owner has a sizeable investment. They are often particularly valuable because of good ground access and proximity to mills. If we do not develop the capability to protect these forest stands, management for the production of a crop, be it Christmas trees, pulpwood, or sawlogs, will be economically senseless.

Outright suspension of pesticides or adjuvants is also a reality. Certain pesticides have been suspended in several jurisdictions in recent years, and in New Brunswick, specific adjuvants have been suspended from use. In other jurisdictions, notice has been served that the continuing use of chemicals, without attempts to develop and use alternatives, is no longer publicly acceptable. Even in New Brunswick, given the very high cost of the program and the intense criticism, the government may well decide to suspend chemical spraying in any given year.

For these reasons, we, as managers, must develop the capability to protect our forest with alternatives to conventional chemical insecticides. We no longer have a choice. We are in an era when we either develop the capability to protect with more acceptable techniques, or we lose our option to protect significant portions of our forest.

The only alternative to chemicals which has potential for immediate operational use is the bacterial insecticide, Bacillus thuringiensis (B.t.). Worth noting is that, at the time "Silent Spring" was published in 1961, scientists in Canada and the United States had already been investigating the mode of action and potential of B.t. for 10 years or more.

Over the past 30 years, the Canadian Forestry Service has carried on a steady (though sometimes modest) research program on B.t., with special attention to its use against spruce budworm. Scientists such as T.A. Angus, W.A. Smirnoff, O.N. Morris and P.G. Fast, all working with the Canadian Forestry Service, and J.B. Dimond at the University of Maine, have persisted through the years and to their credit, as well as many others, we now have a product which is an effective alternative to conventional chemical insecticides.

It has been often said that there are no quick and easy solutions to the budworm problem; the B.t. story simply reinforces that view. It is worth reminding ourselves that it has taken 30 years of effort, including laboratory research, product development, field trials for efficacy and environmental impact, product registration, and politics to bring B.t. to the point where it is in fact an alternative which can be used operationally. Truly, success does not come easily or quickly!

Despite this success, there are still conflicting views about B.t., particularly relating to relative cost and effectiveness. This seminar was organized to give foresters in New Brunswick the opportunity to learn first hand about the experience of several agencies with B.t., and to explore the potential for expanded use of B.t. in New Brunswick. To provide you with information which is relevant and comparable, I have asked the speakers to follow some clear guidelines. They will be relating to you their experience with B.t. primarily in operational programs, not research trials. As mentioned in the program, they will be concentrating on the four factors which are of primary importance in choosing an insecticide:

- cost
- effectiveness for foliage protection
- operational considerations
- environmental constraints

OPERATIONAL USE OF B.T. AGAINST SPRUCE BUDWORM IN ONTARIO, 1979-1983

G.M. HOWSE [1], S.A. NICHOLSON [2] AND J.H. MEATING[1]

[1] Environment Canada, Canadian Forestry Services, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario.

[2] Ontario Ministry of Natural Resources, Forest Resources Branch, Pest Control Section, Maple, Ontario.

INTRODUCTION

The purpose of this paper is to present information and data concerning the operational use of Bacillus thuringiensis (B.t.) against spruce budworm for the past five years in Ontario. Aerial spraying operations in Ontario have been small, particularly in comparison to the total area infested. Such operations are designed to meet the province's needs and generally reflect prevailing forestry conditions. In recent years, protection spraying has been conducted for commercial forests and high value stands including provincial parks, plantations, nurseries, seed production areas and wildlife habitats. Since 1979, some 46,590 ha have been sprayed with slightly more than 43% or 20,235 ha being treated with B.t. During the past two years, some 87-90% of the total area sprayed has been done with B.t. (Table 1).

Tables listing the operational treatments, area treated, costs, pre-spray larval densities and results (in terms of foliage protection) were prepared for each year, 1979-1983 (Tables 2-6). This type of table allows ready comparison of treatments used in a given year in terms of costs and results. Treatments that have a common basis such as material and dosage can be selected from the annual operational summaries and costs and results can be readily compared on a year to year basis (Tables 7-11).

EFFICACY

The primary operational B.t. treatments have been Dipel 88, Novabac 3 and Thuricide 16B applied at a dosage and rate of 20BIU/4.7-5.9 L/ha. The main chemical insecticide treatment has been Matacil mixed with Diluent 585 applied at 90 g/1.4-3.0 L/ha. The treatments selected for cost and effectiveness comparison were all done by small fixed-wing aircraft and were generally single applications. Cost and effectiveness data for each material (Dipel, Novabac,

Thuricide and Matacil) are averaged and presented in a single table (Table 12). These results show that B.t. provides foliage protection approximately equal to that provided by Matacil but that B.t. cost two to three times as much over the five-year period.

COST

A closer look at cost figures (Table 13), based on each year's lowest cost Matacil and B.t. treatments, shows that application and Matacil costs increased each year until 1983 and B.t. costs declined significantly during the past two years. The difference in cost between a standard Matacil and B.t. treatment has been reduced considerably. B.t. treatments no longer cost 2 or 3 times as much as Matacil. The decline in B.t. product costs in recent years (1981 - $.72/BIU, 1982 - $.44/BIU and 1983 - $.32/BIU) is probably the result of competition (three companies) and the tendering process (Table 14).

OPERATIONAL CONSIDERATIONS

Operationally speaking there are a number of problems associated with using B.t. compared to a chemical insecticide, such as Matacil including higher direct (application and materials) and indirect (labor and time) costs, effectiveness (perception of being less effective - particularly against higher populations), no premixing, higher application rates, timing of applications (narrower window), cold weather, shorter shelf life, non-chlorinated neutral pH water required for mixing, label BIU's vs actual, more equipment and manpower required for a B.t. operation, more difficult to achieve good deposit, measuring deposit and lack of availability in bulk. However, there are advantages to using B.t. including safety (human and environmental), effective, selective, less "anti" attitude, resistance less likely to develop, several suppliers (competition), environmental impact studies generally not

necessary, less impact on parasites and oil carrier (such as 585) not required.

ENVIRONMENTAL CONSTRAINTS

In Ontario, there are fewer environmental constraints associated with B.t. usage compared to chemical insecticides. Ministry of Natural Resources policy and procedure requires the establishment of buffer zones in certain situations where chemical insecticides are to be sprayed. However, provision is specifically made to spray the buffer zones with microbials (i.e. B.t.) where appropriate. All programs are reviewed internally at the district and regional level by M.N.R. professional staff such as biologists, parks, fish and wildlife and timber prior to external review. The Ministry of the Environment reviews M.N.R. programs and issues permits. M.O.E. may make amendments or suggest changes but generally programs are conducted with little modification as originally proposed by M.N.R. It is interesting to note that M.O.E. does not have an official policy or even informal guidelines (as far as we are aware) concerning buffers, materials, etc. For example, in 1983 M.O.E. stipulated that a 60-metre buffer be maintained around lakes in a commercial forest spray block treated with B.t. whereas in the same township in a provincial park, a 60-metre zone along a lake edge was treated with B.t. with no stipulation for a buffer zone. It was not only in the same township but was the same water system. No one is aware of the reasons for the distinction made in 1983 and undoubtedly such interpretations will cause problems in the future.

RECOMMENDATIONS

In conclusion, we wish to offer a few suggestions or recommendations that may improve the effectiveness and/or lower the cost of B.t.: lower dosages, lower application

volumes, more effective strains, better formulations, higher BIU content, shipping in bulk, one versus two applications and additives such as feeding enhancers or attractants and sunlight protectants.

CONCLUSIONS

EFFICACY - Formulations of B.t. used operationally in Ontario have provided results in terms of foliage protection that are generally comparable to or in some cases better than Matacil.

COST - In Ontario, the difference in costs of using B.t. compared to Matacil has decreased to the point where B.t. is no longer at a serious disadvantage.

OPERATIONAL CONSIDERATIONS

- B.t. is a safe material to handle and aerially spray. The major problems with using B.t. in Ontario have been timing, handling and cold weather.

ENVIRONMENTAL CONSTRAINTS

- There are fewer constraints associated with the use of B.t. compared to Matacil in Ontario, although this situation is not formally recognized in guidelines or regulations by a provincial agency such as the Ministry of the Environment.

Table 1. Area (ha) of operational aerial spraying against spruce budworm in Ontario, 1975-1983.

YEAR	TOTAL	B.T.	CHEMICAL	% B.T.
1975	13,500	0	13,500	0
1976	39,468	768	38,700	2
1977	3,855	0	3,855	0
1978	200	0	200	0
1979	20,250	3,454	16,796	17
1980	9,948	4,374	5,574	44
1981	9,801	6,576	3,225	67
1982	3,429	3,068	361	90
1983	3,162	2,763	399	87

Table 2. Summary of spruce budworm operational spraying data (treatments, costs and results) for Ontario, 1979. Treatments were single applications made by small fixed-wing aircraft.

	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE [2]	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT [1]
THURICIDE 16B (10 BIU/4.7 L/ha)	1,580	$ 8.87	$0.89	bF	13	7	82	91
				wS	26	12	74	84
THURICIDE 16B (2X) (10 BIU/4.7 L/ha)	198	$15.57	$0.78	wS	25	25	74	66
THURICIDE 16B (2X) (10 BIU/4.7 L/ha)	860	$15.12	$0.76	bF	16	55	71	23
				wS	29	63	76	17
				bS	7	42	65	35
NOVABAC 32B (2X) (20 BIU/4.7 L/ha)	175	$39.00	$0.98	bF	36	55	93	41
				wS	47	72	84	14
ORTHENE (280 g/1.5 L/ha) +NOVABAC 32B (20 BIU/4.7 L/ha)	809	$17.96		bF	25	80	76	0
				wS	47	69	85	19
				bS	9	50	65	23
MATACIL (63 g/1.0 L/ha)	9,597	$ 2.99		bF	31	70	90	22
				wS	48	48	72	33
MATACIL (88 g/1.5 L/ha)	5,666	$ 3.39		bF	20	60	74	19
				wS	24	63	72	13
				bS	11	24	68	65

TOTAL AREA SPRAYED = 20,250 ha.

AVERAGE COST = $5.76/ha.

1 $\%\ PROT = \frac{\%\ Defoliation\ Check - \%\ Defoliation\ Spray}{\%\ Defoliation\ Check} \times 100$

2 Larvae/45 cm. branch

Table 3. Summary of spruce budworm operational spraying data (treatments, costs and results) for Ontario, 1980. Treatments were single applications made by small fixed-wing aircraft.

	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT
DIPEL 88 (20 BIU/9.4 L/ha)	567	$24.08 (est.)	$1.20	bF	24	48	71	32
				wS	29	50	60	17
THURICIDE 16B (20 BIU/9.4 L/ha)	283	$23.17	$1.16	bF	49	62	93	33
				wS	67	70	66	0
NOVABAC 3 (25 BIU/4.7 L/ha)	1,716	$11.61	$0.46	bF	22	28	86	67
				wS	25	27	77	65
NOVABAC 3 (2X) (25 BIU/4.7 L/ha) +NOVABAC OR THURICIDE 16B (15 BIU/4.7 L/ha)	2,160	$23.22	$0.58	bF	19	18	86	79
				wS	21	41	77	47
MATACIL (86 g/1.4 L/ha) +NOVABAC (25 BIU/4.7 L/ha)	429	$15.56		bF	36	10	98	90
				wS	44	32	85	62
MATACIL (2X) (86 g/1.4 L/ha)	3,596	$ 7.90		bF	13	29	84	65
				wS	14	36	73	51

TOTAL AREA SPRAYED = 9,948 ha.

AVERAGE COST = $16.29/ha.

Table 4. Summary of spruce budworm operational spraying data (treatments, costs and results) for Ontario, 1981. Treatments were single applications made by small fixed-wing aircraft.

	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT
DIPEL 88 (20 BIU/5.9 L/ha)	846	$21.44	$1.07	bF	3	4	34	88
				wS	6	10	22	55
DIPEL 88 (20 BIU/5.9 L/ha)	1,099	$24.08	$1.20	bF	15	40	56	29
				wS	17	13	30	57
THURICIDE 16B (20 BIU/7.0 L/ha)	670	$24.44	$1.22	bF	7	33	77	57
				wS	18	63	64	2
MATACIL (86 g/3.0 L/ha)	2,424	$ 9.43 [1]		bF	6	4	34	88
				wS	9	7	22	68
MATACIL (86 g/3.0 L/ha)	547	$12.86		bF	12	4	56	93
				wS	16	3	30	90

TOTAL AREA SPRAYED = 9,801 ha.

AVERAGE COST = $21.30/ha.

[1] Includes navigation (Flying Flagman) costs of $2.72/ha.

Table 5. Summary of spruce budworm operational spraying data (treatments, costs and results) for Ontario, 1982. Treatments were single applications made by small fixed-wing aircraft.

	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE	% DEFOLIATION		% PROT
						SPRAY	CHECK	
DIPEL 88 (20 BIU/5.9 L/ha)	2,439	$15.00	$0.75	bF	18	27	64	58
				wS	19	31	70	56
NOVABAC 3-e (20 BIU/5.9 L/ha)	172	$28.00	$1.40	bF	10	14	79	82
				wS	13	32	70	54
MATACIL (90 g/3.0 L/ha)	136	$10.60		bF	6	12	74	84
				wS	7	9	35	74

TOTAL AREA SPRAYED = 3,429 ha.

AVERAGE COST = $20.12/ha.

Table 6. Summary of spruce budworm operational spraying data (treatments, costs and results) for Ontario, 1983. Treatments were single applications made by small fixed-wing aircraft.

	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT
DIPEL 88 (20 BIU/5.9 L/ha)	1,553	$19.40	$0.97	bF	6	5	55	91
				wS	7	8	40	80
NOVABAC 3 (20 BIU/5.9 L/ha)	1,210	$16.81	$0.84	bF	6	5	55	91
				wS	12	9	55	84
MATACIL (90 g/3.0 L/ha)	399	$14.40 [1]		bF	25	36	95	62
				wS	30	31	85	o4

TOTAL AREA SPRAYED = 3,162 ha.

AVERAGE COST = $15.84/ha.

1 Includes navigation (Flying Flagman) costs of $5.67/ha.

Table 7. Costs and results of operational spraying of Dipel 88 at 20 BIU/5.9 L/ha in Ontario, 1980-1983. All treatments were single applications by small fixed-wing aircraft.

	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT
1980	567	$24.08 (est.)	$1.20	bF	24	48	71	32
				wS	29	50	60	17
1981	1,099	$24.08	1.20	bF	15	40	56	29
				wS	17	13	30	57
1981	846	$21.44	$1.07	bF	3	4	34	88
				wS	6	10	22	55
1982	2,439	$15.00	$0.75	bF	18	27	64	58
				wS	19	31	70	56
1983	1,553	$19.40	$0.97	bF	6	5	55	91
				wS	7	8	40	80

Table 8. Costs and results of operational spraying of Novabac 3 at 20-40 BIU/4.7 L - 5.9 L/ha in Ontario, 1979-1980 and 1982-1983. All treatments were single or double applications by small fixed-wing aircraft.

	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT
1979								
20 BIU/4.7 L/ha (2X)	175	$39.00	$0.98	bF	36	55	93	41
				wS	47	72	84	14
1980								
25 BIU/4.7 L/ha	1,716	$11.61	$0.46	bF	22	28	86	67
				wS	25	27	77	65
25 BIU/4.7 L/ha +15 BIU/4.7 L/ha	2,160	$23.22	$0.58	bF	19	18	86	79
				wS	21	41	77	47
1982								
20 BIU/5.9 L/ha	172	$28.00	$1.40	bF	10	14	79	82
				wS	13	32	70	54
1983								
20 BIU/5.9 L/ha	1,210	$16.81	$0.84	bF	6	5	55	91
				wS	12	9	55	84

Table 9. Costs and results of operational spraying of Thuricide 16B at 10-20 BIU/ha in Ontario, 1979-1981. All treatments were single or double applications by small fixed-wing aircraft.

	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT
1979								
10 BIU/4.7 L/ha	1,580	$ 8.87	$0.89	bF	13	7	82	91
				wS	26	12	74	84
10 BIU/4.7 L/ha (2X)	198	$15.57	$0.78	wS	25	25	74	66
10 BIU/4.7 L/ha (2X)	860	$15.12	$0.76	bF	16	55	71	23
				wS	29	63	76	17
				bS	7	42	65	35
1980								
20 BIU/9.4 L/ha	283	$23.17	$1.16	bF	49	62	93	33
				wS	67	70	66	0
1981								
20 BIU/7.0 L/ha	670	$24.44	$1.22	bF	7	33	77	57
				wS	18	63	64	2

Table 10. Costs and results of operational spraying of Matacil in Ontario, 1979-1983. All treatments were single applications (except 1980) by small fixed-wing aircraft.

	AREA	COST/HA	HOST	PRE-SPRAY LARVAE	% DEFOLIATION		
					SPRAY	CHECK	% PROT
1979							
63 g/1.0 L/ha	9,597	$ 2.99	bF	31	70	90	22
			wS	48	48	72	33
88 g/1.5 L/ha	5,666	$ 3.39	bF	20	60	74	19
			wS	24	63	72	13
			bS	11	24	68	65
1980							
86 g/1.4 L/ha (2X)	3,596	$ 7.90	bF	13	29	84	65
			wS	14	36	73	51
1981							
86 g/3.0 L/ha	2,424	$ 9.43	bF	6	4	34	88
			wS	9	7	22	68
86 g/3.0 L/ha	547	$12.86	bF	12	4	56	93
			wS	16	3	30	90
1982							
90 g/3.0 L/ha	136	$10.60	bF	6	12	74	84
			wS	7	9	35	74
1983							
90 g/3.0 L/ha	399	$14.40	bF	25	36	95	62
			wS	30	31	85	64

Table 11. Costs and results of operational spraying treatments of a chemical insecticide followed by B.t. in Ontario, 1979 and 1980. All treatments were single applications of each material applied by small fixed-wing aircraft.

	AREA	COST/HA	HOST	PRE-SPRAY LARVAE	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT
1979							
ORTHENE (280 g/1.5 L/ha) +NOVABAC (20 BUI/4.7 L/ha)	809	$17.96	bF	25	80	76	0
			wS	47	69	85	19
			bS	9	50	65	23
1980							
MATACIL (86 g/1.4 L/ha) +NOVABAC (25 BIU/4.7 L/ha)	429	$15.56	bF	36	10	98	90
			wS	44	32	85	62

Table 12. Summary of average costs and results of operational spraying treatments of B.t. and Matacil in Ontario, 1979-1983.

MATERIAL	AREA	COST/HA	COST/BIU	HOST	PRE-SPRAY LARVAE	% DEFOLIATION SPRAY	% DEFOLIATION CHECK	% PROT
DIPEL 88 20 BIU/ha	6,504	$20.80	$1.04	bF	13	25	56	55
				wS	16	22	44	50
THURICIDE 16B 10-20 BIU/ha	3,591	$17.43	$0.96	bF	21	39	81	52
				wS	33	47	71	34
				bS	7	42	65	35
NOVABAC 20-40 BIU/ha	5,433	$23.73	$1.19-$0.59	bF	19	24	80	70
				wS	24	36	73	51
MATACIL 63-172 g/ha	22,365	$ 8.80		bF	16	31	72	57
				wS	21	28	56	50
				bS	11	24	68	65
ORTHENE OR MATACIL + B.t.	1,238	$16.76		bF	31	45	87	48
				wS	46	51	85	40
				bS	9	50	65	23

Table 13. Costs ($/ha) for Matacil and B.t. treatments, Ontario, 1979-1983.

	MATACIL (90 g/ha)			B.T. (20 BIU/ha)			
	APPLICATION	MATERIAL	TOTAL	APPLICATION	MATERIAL	TOTAL	DIFF.
1979	1.31	2.08	3.39	2.62	12.50(T)	15.12	11.73
1980	1.84	2.11	3.95	2.04	9.57(N)	11.61	7.66
1981	4.35 [1]	2.36	6.71	4.35 [1]	14.37(D)	18.72	12.01
1982	6.40	4.20	10.60	6.32	8.68(D)	15.00	4.40
1983	5.05 [2]	3.68	8.73	5.05 [2]	6.09(N)	11.14	2.41

[1] Flying Flagman 2.72/ha in addition to application costs.

[2] Flying Flagman 5.67/ha in addition to application costs.

(T) Thuricide 16B, (N) Novabac 3, (D) Dipel 88.

Table 14. Costs of various B.t. products in Ontario, 1979-1983.

Year	Supplier	Formulation	BIU/L	$/L	$/BIU	$/Ha	Method of purchase
1979	Cyanamid	Nov 3	8.64	3.90	.4510	9.02	O [1]
	Sandoz	Th 16	4.23	2.84	.6710	13.42	O
1980	Abbott	Dip 88	8.45	6.08	.7195	14.59	T [2]
	Cyanamid	Nov 3	8.64	5.02	.5810	11.62	T
	Sandoz	Th 16	4.23	3.11	.7352	14.72	T
1981	Abbott	Dip 88	8.45	6.08	.7195	14.39	O
	Sandoz	Th 16	4.23	3.01	.7116	14.27	O
1982	Abbott	Dip 88	8.45	3.64	.4308	8.62	T
	Biochem	Nov 3	8.64	2.89	.3344	6.68	T
	Sandoz	Th 32LV	8.45	4.60	.5440	10.88	T
	Biochem	Nov 3	8.64	8.75	1.0127	20.26	O
1983	Abbott	Dip 88	8.45	2.88	.3408	6.82	T
	Biochem	Nov 3	8.64	2.63	.3044	6.09	T
	Sandoz	Th 32LV	8.45	2.72	.3219	6.44	T

[1] O-ordered, [2] T-tendered

OPERATIONAL EXPERIENCE WITH B.T. IN QUEBEC
1980-1983

J.G. DAVIDSON [1]

[1] Ministère de l'Énergie et des Ressources, Québec, Québec

Table 1. Aerial treatments with Bacillus thuringiensis conducted on Quebec forests in 1980 to control Spruce Budworm.

Area:		Operational (Thuricide)	20,971 ha
		Experimental (Dipel)	1,209 ha
		Total (Lower St. Lawrence)	22,180 ha
Insecticide:		Thuricide 32B, Dipel 88	
Dosage:		Operational	29.64 BIU/ha
		Experiemental	19.54 BIU/ha
Volume:		7.0 L/ha	
Formulation:	1)	Thuricide 32B	50%
		Water	30%
		Sorbitol	20%
		Chevron sticker	1/1600
		Chitinase	9884 UN/ha
	2)	Dipel 88	33%
		Water	67%
		Chevron sticker	1/1600
		Chitinase	9884 UN/ha
Timing:		Bud Flush	
Aircraft:		L-749	Speed: 330 km/h
			Altitude: 100 m
			Swath: 150 m
			Capacity: 9463 L
Spray System:		154 open nozzles	
Weather Conditions:		Wind speed: <12 km/h	
		Absence of thermic turbulence	

Table 1. Continued

RESULTS

TREATMENTS	DEPOSIT (colonies/cm^2)	EFFICACY		
		Pre-spray population (larvae/branch)	Larval mortality (%)	Defoliation (%)
Thuricide 32B	26.2	9.7	82	26
Dipel 88	16.2	6.4	87	17
Check Thuricide	-	9.7	40	55
Check Dipel 88	-	6.4	60	36

CONCLUSIONS - 1980

1. Populations were too low to make general conclusions regarding efficacy but against low populations ($\simeq$ 10 larvae/branch), 20 BIU seems to be sufficient to kill larvae and to protect some foliage.

2. Deposit from both formulations seems to be very good suggesting the possibility of a volume reduction from 7 L/ha to 5.85 L/ha.

3. Swath of 150 m should be improved with new pumping system.

4. Deposit of Dipel 88 mixed in oil shows very fine droplets similar to chemical deposit and 15 droplets/cm^2 seems to be sufficient to give similar results to water base formulation.

5. Addition of Sorbitol is not required with Dipel 88 presenting an easier situation regarding manipulation.

6. No restriction regarding environmental hazard. The only restriction made is around villages to avoid dye on houses or cars.

7. The average cost of insecticide and adjuvants was $15.07/ha and the cost of aerial application was $8.93/ha for a total of $24.00/ha.

Table 2. Aerial treatments with Bacillus thuringiensis conducted on Quebec forests in 1981 to control Spruce Budworm.

Area:	Operational (Dipel 88)	12,188	ha
	Experimental (Thuricide 32-B)	1,875	ha
	(Futura 64B)	938	ha
	Total (Lower St. Lawrence Area)	15,001	ha

Insecticide: Thuricide 32B, Dipel 88, Futura 64B

Dosage: 19.76 BIU/ha

Volume:

Operational	7 L/ha
Experimental	5.85 L/ha (Thuricide)
	2.34 L/ha (Futura)

Formulation:

1)

Dipel 88	33%
Water	67%
Chevron Sticker	1/1600
Chitinase	9884 UN/ha

2)

Thuricide 32B	40%
Water	36%
Sorbitol	24%
Chevron Sticker	1/1600
Chitinase	9884 UN/ha

3)

Futura	50%
Water	50%

Timing: Bud Flush

Aircraft: L-749

Speed:	330 km/h
Altitude:	100 m
Swath:	305 m
Capacity:	9463 L

Spray System: 154 open nozzles

Weather Conditions: Wind speed: < 12 km/h
Absence of thermic turbulence

Table 2. Continued

RESULTS

TREATMENTS	DEPOSIT (colonies/cm^2)	EFFICACY		
		Pre-spray population (larvae/branch)	Larval mortality (%)	Defoliation (%)
Dipel 88	No data	10.6	89.6	15
Check	-	12.1	61.0	41
Thuricide 32B	19.4	24.4	82.7	32
Futura 64B	15.5	16.1	57.1	74
Check	-	21.0	60.0	64

CONCLUSIONS - 1981

1. Populations were low ranging from 10-15 larvae/branch but at this level a dosage of 20 BIU/7L/ha succeeded to kill larvae and to protect foliage.

2. Experimental treatments with lower volume gave very good results, using 5.85 L/ha even if populations were high (25 larvae/branch). With a volume of 2.34 L/ha, results were poor, associated with inadequate calibration.

3. Deposit of experimental formulation was lower than previous years and less homogeneous: lower volume/ha and swath of 305m could be responsible for this.

4. The viscosity of the FUTURA formulation will require new agitation system if the product is to be used operationally.

5. Still no restriction regarding environmental hazard.

6. The average cost of insecticide and adjuvants was $13.28/ha and the cost of aerial applications was $8.76/ha for a total of $22.04/ha.

Table 3. Aerial treatments with Bacillus thuringiensis conducted on Quebec forests in 1982 to control Spruce Budworm.

Area:	Operational (Dipel 88)	12,345 ha
	(Thuricide 32 LV)	15,626 ha
	Experimental (FUTURA)	3,906 ha
	Total (Lower St. Lawrence Area)	31,877 ha

Insecticide:	Dosage (BIU/ha)	Volume (L/ha)	Formulation % Bt	water	Chevron sticker
Dipel 88	20	5.8	40	60	1/1600
	30	8.8	40	60	1/1600
	30	3.5	100	-	1/1600(DC 4)
Thuricide 32 LV	20	4.6	50	50	1/1600
	30		75	25	1/1600
	40		100	-	1/1600
FUTURA	20	2.5	60	40	1/1600(DC 4)

Timing: Bud Flush

Aircraft:			
	AgCaDB	Speed:	176 km/h
		Altitude:	15 m
		Swath:	30 m
		Capacity:	946 L
		Navigation:	pointer (visual)
		Spray system:	40 nozzles 8004-8006
	DC-4G	Speed:	280 km/h
		Altitude:	100 m
		Swath:	305 m
		Navigation:	LITTON I.N.S.
		Spray system:	100 open nozzles for FUTURA

Weather Condition: Wind speed: <12 km/h
Absence of thermic turbulence

Table 3. Continued

RESULTS

TREATMENTS	DOSAGE & VOLUME	EFFICACY		
		Pre-spray population (larvae/branch)	Larval mortality (%)	Defoliation (%)
Thuricide 32 LV	20 BIU/4.68L/ha	16.2	79	48
Check			52	85
Thuricide 32 LV	40 BIU/4.68L/ha	11.0	82	57
Check			45	79
Dipel 88	20 BIU/5.9 L/ha	22.7	85	76
Check			50	85
Dipel 88	30 BIU/8.8 L/ha	18.0	83	40
Check			71	90
Dipel 88	30 BIU/3.5 L/ha	22.0	91	69
Check			63	92
FUTURA	20 BIU/2.5 L/ha	23.0	87	43
Check			68	100

CONCLUSION - 1982

1. The use of small aircraft to spray Bt. was inadequate because the volume/ha to be applied is high: one third of the original program was not done.

2. As soon as populations get higher than 20 larvae per branch, a dosage of 30 BIU/ha is required to get results.

3. Deposit evaluation was postponed until the development of a more reliable technique.

4. Late timing of some treatment placed us in a bad position to draw firm conclusions from the 1982 treatments.

5. FUTURA gave very good results even if populations were high (23 larvae/branch). The product is still hard to mix, very heavy (13 pds/usg) and not registered but still very promising regarding efficacy.

6. Concentrated material seems to be the ideal way to reduce volume and cost of Bt. treatment.

7. Absence of Chitinase does not seem to influence resuts.

8. The average cost of insecticide and adjuvants was $11.81/ha and the cost of aerial application was $4.63/ha for a total of $16.44/ha.

Table 4. Aerial treatments with Bacillus thuringiensis conducted on Quebec forests in 1983 to control Spruce Budworm.

Area:

Operational	(Novabac 3)	10,626 ha
	(Dipel 88)	13,906 ha
Experimental	(Dipel 88)	12,188 ha
	(Novabac 3)	4,219 ha
	(Futura)	4,688 ha
Total (Lower St. Lawrence area)		45,627 ha

Insecticide:	Dosage (BIU/ha)	Volume (L/ha)	Formulation (%) Bt	water	sorbitol	sticker
Dipel 88	20	5.85	40.5	59.5	-	1/1600
Novabac 3	20	4.68	50	30	20	1/1600
	30	6.6	54	26	20	1/1600
Futura	20	2.5	60	40	-	1/1600

Timing: Bud Flush

Aircraft: DC-4G

Speed:	280 km/h
Altitude:	100 m
Swath:	305 m
*Capacity:	9400 L
Navigation:	LITTON I.N.S.
Spray system:	154 open nozzles

*Capacity: 8200 L for FUTURA
Spray system: 110 open nozzles near the fuselage

Weather conditions: Wind speed: $<$12 km/h
Absence of thermic turbulence

Table 4. Continued

RESULTS

TREATMENTS

1. Operational — Not available at this time.

2. Experimental

	DEPOSIT (colonies/cm^2)	EFFICACY		
		Pre-spray population (larvae/branch)	Larval mortality (%)	Defoliation (%)
Dipel 20 BIU/5.85L/ha	11.6	36.4 ± 4.8	93.4	41
Check		36.0 ± 4.2	70.0	91
Novabac 30 BIU/6.6L/ha	20.6	34.0 ± 3.9	92.1	55
Check		33.7 ± 3.6	65.0	93
Futura 20 BIU/2.5L/ha	11.3	50.6 ± 5.5	94.1	50
Check		48.0 ± 5.2	72.1	97

CONCLUSIONS - 1983

1. Treatments were conducted against very high populations ranging from 35 to 50 larvae per branch. Results were very good in experimental blocks with late budworm development and desynchronisation of the shoot elongation ahead of the insect.

2. Increasing the volume will increase the deposit but not necessarily the efficacy. This point raises question about importance of spores vs. crystals. Deposit appeared to be less abundant than previous year but must be considered comparable because for the first year contamination was separated from true B.t. colonies.

3. Operational restriction of mixing the product just prior to application limits the use of B.t. to one load per spray period. Tests have been undertaken to determine how long B.t. formulation could remain in tanks without losing potency. Preliminary results show no lost of potency after five days.

4. Futura remains the most promising product; low dosage and volume gave for two years in a row good results. The weight of the product (8200 L vs. 9400 L/load with other formulations), the mixing process and the registration still needs development.

5. Calibration trials are undertaken to use other, more concentrated products (Dipel 132, 176 and Thuricide 48, 64) which still remains the way to reduce volume and cost.

6. Development of mixing system has to be improved if product is applied neat.

7. For the first year 1 km buffer zones were requested around inhabited areas, drinking water points and farming lands (advice from public Hearing's Bureau).

8. The average cost of insecticide and adjuvants was $6.14/ha and the cost of aerial application was $14.44/ha for a total of $20.58/ha.

Summary of Costs

In general, the price of chemical insecticide formulations has increased from 6 to 25% (mean 10%) per year while the prices of B.t. formulations have decreased from 5 to 57% (mean 20%) per year. The 1983 B.t. costs per BIU vary from $0.33 to $0.48. (Table 5)

The 1983 treatment costs of chemical insecticides vary from $3.70 to $4.38 per sprayed hectare for a double application compared with B.t. from $5.19 to $7.64 per sprayed hectare for a single application with registered products.

The average costs of B.t. insecticide and adjuvants per treated hectare have decreased from $15.07 in 1980 to $6.14 in 1983 while the average costs of aerial application have increased from $8.76 to $14.44 (Table 6). It should be observed that it is only since 1982 that we have tenders for B.t. aerial application. Before that, B.t. aerial application costs were included with chemical insecticide costs.

Finally, the 1983 relative cost of B.t. and chemical insecticides is $6.14 compared to $3.23 for insecticide and adjuvants and $14.44 compared to $3.21 for aerial application (Table 6).

TABLE 5. THE COST OF B.T. AND CHEMICAL INSECTICIDES FORMULATION PER APPLICATION

DESCRIPTION	1981		1982		1983		
	$/L(Kg)	$/ha[1]	$/L(Kg)	$/ha	$/L(Kg)	$/ha	$/BIU
Dipel 88	4.92	10.99	3.57	7.98	3.03	7.17	0.36
Novabac - 3	4.07	10.37[2]	3.75	9.86[2]	2.19	5.19[2]	0.33
Thuricide 32 LV			3.64	8.12[3]	2.92	7.64[2]	0.41
Thuricide 32 B	4.76	11.91[2]					
Futura II (not registered)			6.08	8.51	6.92	9.69	0.48
Fenitrothion (210 g/ha)		1.91[4]		2.03[4]		2.19[4]	
Matacil (52.5 g/ha)		1.36[5]		1.69[5]		1.85[5]	

[1] Sprayed hectare

[2] Including sorbitol

[3] Without sorbitol

[4] Including diluent 585 and Cyclosol 63

[5] Including diluent 585

TABLE 6. AVERAGE COST PER TREATED HECTARE OF AERIAL SPRAYING WITH A FOUR-ENGINE AIRCRAFT BY TREATMENT AGAINST SPRUCE BUDWORM IN QUEBEC FROM 1980 - 1983.

DESCRIPTION	YEAR				
	1980	1981	1982	1983	
	NUMBER OF TREATED HECTARES				
	B.t. 22,180	B.t. 15,001	B.t. 31,877	B.t. 45,627	Chemical Insecticides 1,207,978
INSECTICIDE AND ADJUVANTS	15.07	13.28	11.81	6.14	3.23*
AERIAL APPLICATION	8.93	8.76	4.63**	14.44	3.21*
TOTAL	24.00	22.04	16.44	20.58	6.44

* For a double application

** For a single-engine aircraft

Current Assessment - 1983

A) Cost

The 1983 average treatment costs of B.t. are $6.14 for insecticide and adjuvants and $14.44 for aerial application per treated hectare.

B) Efficacy of B.t. formulation

1. Dosage:

As long as light to moderate defoliation is anticipated, treatment can be done at dosage of 20 BIU/ha.

When severe defoliation is anticipated (pop: 25 larvae per branch or more) 30 BIU/ha appears to be a more reliable dosage to get consistant results.

2. Volume:

Technology developed in Quebec is mainly oriented with four engine aircraft; up to now, for registered formulations, a volume of 4.68 to 5.85 L/ha is required to ensure consistant results.

Meanwhile the development of more concentrated material allows a reduction of the volume/ha providing as good results as the other formulation (FUTURA II, 2.5 L/ha).

3. Formulation:

Oil base formulations give finer droplets and more homogeneous deposit than water base formulations but require very high volume of water to avoid inverted emulsion unless applied neat.

There would be a lot of advantage to apply the products neat and effort should be directed to more concentrated products.

Because of restrictions from Agriculture Canada, Chitinase has not been used for the last two years in the formulations.

C) Operational constraints

Formulated B.t. is known to lose potency with time; considering the cost of the product and probability of treament, the product is mixed just prior to application presenting a heavy operational constraint. Such a restriction disappeared with the product applied neat but new agitation system would be required to ensure homogeneous suspension.

Associated with evidence that the crystal, not the spore is responsible for larval kill, bioassays should be undertaken to evaluate how long the formulated B.t. could stay without losing its potency.

Tests should also be undertaken to dye the B.t. crystal and develop a more reliable technique to evaluate deposit that could be associated with efficacy, which up to now, can not be associated with droplet size or droplet number.

D) Environmental constraints

Since 1983, buffer zones of 1 km have been requested by the Quebec Department of Environment near inhabited areas, drinking water points and lands under cultivation.

OPERATIONAL USE OF B.T. IN NEW BRUNSWICK
PART 1. COSTS, OPERATIONAL CONSIDERATIONS AND ENVIRONMENTAL CONSTRAINTS

H.J. IRVING [1]

[1] Forest Protection Ltd., Fredericton, N.B.

ENVIRONMENTAL AND REGULATORY CONSTRAINTS

Regulatory constraints in New Brunswick scarcely recognize the greater environmental safety of B.t. The same constraints that are placed on fenitrothion were applied to B.t. in 1983 with only one exception: spraying of B.t. was permitted up to 155 meters from principal residences whereas fenitrothion was forbidden closer than 300 meters. For both materials spraying was forbidden (1) closer than 3.2 km from the point of extraction of any municipal surface drinking water supply, and (2) closer than 65 meters of other open surface water.

OPERATIONAL CONSIDERATIONS

(1) Such technical guidance as exists on weather for B.t. spraying is difficult to interpret and to apply operationally. A couple of scenarios illustrate the problem.

(a) Instead of forecast rain, conditions at 0530 are overcast with light winds - ideal spray weather. With chemicals the course of action is clearly to begin spraying and continue until precipitation starts provided other parameters remain favorable. This is essential in major operations in which every endeavor must be made to use and not to miss available spraying hours. Forecast rain frequently does not materialize and equally often non-forecast showers occur. Are more rigidly defined rules required or operationally sensible for B.t.?

(b) If rain occurs shortly following B.t. spraying how important is it to respray if the proponent is prepared to accept the cost? Permit and label information do not clearly indicate whether to do so would be within or out-side the spray licence.

(2) The utility of adjuvants appears to be uncertain. F.P.L. added a sticker in 1983 as a precaution but under the impression that the only one registered for use in Canada is regarded as one of the least effective brands. Operators elsewhere and manufacturers generally are also equivocal or undecided about anti-evaporants; some claim benefits, others do not.

(3) Although some operators remain satisfied with boom and nozzle equipment F.P.L. has opted for rotary atomizers in the belief that a technological preference is swinging in their direction. The Novabac 3 formulation used this year was characterized through Micronair atomizers at the Cranfield Institute of Technology, England. From this it appeared that the droplet spectrum giving the best impingement would result from three parts of Novabac 3 to one part of water with a blade setting giving maximum safe unloaded rpm. However the validity of such laboratory-established calibration has been placed somewhat in question by the discovery that loaded rpm in practice is somewhat less than in wind tunnels at the same blade setting and windspeed. This and the added complication that performance of individual units varies somewhat according to their location on the aircraft indicate still undefined influences of turbulence created by the wings and prop wash. Added to this is the acknowledgement by B.t. manufacturers that in their continuing development, subtle and sometimes not-so-subtle changes occur in their products from year to year under the same name and specifications.

(4) Operational practice is also faced with the uncertainty of how much, if any, dilution is wise for the several available products, and what droplet spectrum to aim for. There appears to be some concern, e.g. that too much dilution will result in a sub-lethal dose from which larvae might recover and on the other hand that too widely spaced, larger droplets might result in considerable feeding before larvae encounter a lethal deposit.

No major operational problems were encountered in the mechanics of mixing, loading and spraying the B.t. formulation used in 1983.

Assessments of efficacy in biological terms were the responsibility of D.N.R. in 1983, with technical guidance from the M.F.R.C. Reports on these aspects are to be presented by F.G. Kettela.

COSTS

Many factors influence total costs. The true costs of spraying woodlot areas with either fenitrothion or B.t. cannot be extracted accurately from F.P.L. accounting records because they are so intimately a part of the overall program costs. F.P.L. has carried out spray projects of about 4 million acres for the past several years mostly in the so-called Industrial Zone. The proportion of woodlot area to the total has never exceed 6% and the proportion of B.t. has never exceeded one percent.

Nevertheless the F.P.L. experience can be used in a general way to put the costs of using B.t. in perspective and these costs can be subdivided into three categories:

(1) Spray Materials
(2) Application and Ground Support
(3) Overhead

(1) Spray Materials Costs

The F.P.L. fenitrothion formulation is the basis for cost comparison in the following review:

Spray Material Costs - Canadian Currency

	Fenitrothion	B.t.
1980	$3.10 lb.	Thuricide 16B - $0.67/BIU
1981	3.24 lb.	No purchase
1982	3.44 lb.	Dipel 88 - $0.53/BIU
1983	3.69 lb.	Novabac 3 - $0.31/BIU

Application Rates/Acre

(U.S. Fluid Ounces)

	Fenitrothion (2 applications)	B.t. (single application)
1980		8 BIUs in 128 fl. oz.
1981	Total each year:	--------
1982	6 oz. avoir in 40 fl. oz.	12 BIUs in 48 fl. oz.
1983		12 BIUs in 64 fl. oz.

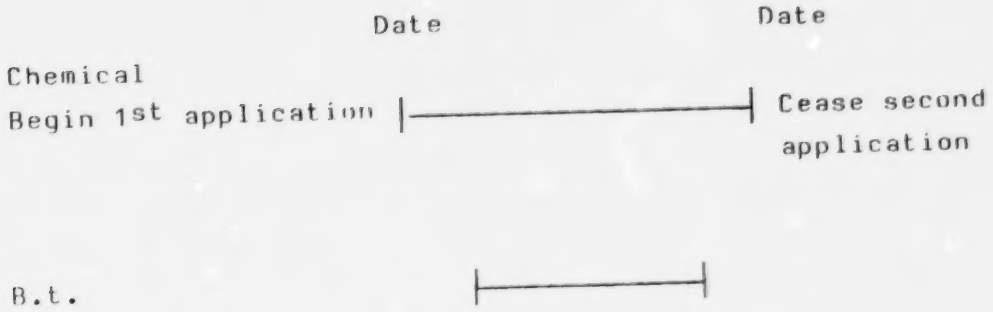
Formulation Cost Per Acre

	Fenitrothion	B.t.
1983	$1.53	$3.72

(2) Application and Ground Support Costs

For 1983 woodlot spraying of 202,800 acres F.P.L. books show expenditures of $750,529 ($3.70/acre) exclusive of spray materials and overhead. In comparing application costs of B.t. with chemicals the time available for application must be considered.

Entomologists who provide the information on which block openings and closings are based advise that the time window is something like this for foliage protection:



That is, one can start at an earlier date and carry on to a later date with chemical than with B.t. and still achieve effective foliage protection, the time relationship probably being about 2 to 1. The spray aircraft operator (indeed almost any aircraft operator) is primarily interested in aircraft earnings per season rather than the number of days worked or hours flown. Aircraft operational costs are heavily weighted to seasonal or annual costs (fixed) rather than work performed (variable).

Thus the ratio of workload required per unit area for B.t. application of 64 ounces to two chemical applications of 20 ounces each becomes:

$$\frac{64}{40} \times \frac{2}{1} = 3.2/1$$

Due to the small proportion of B.t. being applied in relation to chemical it has been easy for F.P.L. to utilize aircraft and flight crews already in place for the chemical sprays. However, if aircraft must be dedicated to B.t. application only, the principle just discussed applies. To rephrase this:

(a) A much larger airforce and related ground support is required for B.t. spraying; and

(b) the risk of unfavourable weather interfering with the project is greater.

(3) Overhead Costs

Overhead assessment of $2,267,000 was approved for sharing by the sponsors of F.P.L. for 1983 as the cost of maintaining a nucleus of personnel and support capable of administering and being expanded to implement a 2 to 5 million acre spray project. This amounts to $0.57 per acre from a 4 million acre project and $0.76 per acre for a 3 million acre project.

COST ESTIMATES PER ACRE*

	Large Aircraft-Large Blocks 4 Million Acres		Small Aircraft-Small Blocks 3 Million Acres**	
	Fenitrothion	B.t.	Fenitrothion	B.t.
Spray Materials	1.53	3.72	1.53	3.72
Application and Ground Support	1.44 x 3.2 = 4.61		3.70 x 3.2 = 11.84	
Overhead	.57	.57	.76	.76
TOTAL PER ACRE	3.54	8.90	5.99	16.32

* Expenditures on which these estimates are based are subject to minor revision since they include expenditures to date and budget extensions to the end of the fiscal year. Woodlot spraying costs are not expected to change significantly.

** Small block, small aircraft spraying has been estimated for 3 million acres rather than 4 on the assumption that by closer targetting, avoiding more non-susceptible and low value areas, a 25% reduction could be achieved.

More potent formulations of B.t. have been developed and are expected to be registered in Canada soon. A formulation permitting 12 BIUs per acre in 30 U.S. fluid ounces would give a 1.5/1 ratio instead of the 3.2/1 used above and substantially reduce the difference in application costs between the two materials.

OPERATIONAL USE OF B.T. IN NEW BRUNSWICK
PART 2. EFFICACY

E.G. KETTELA [1]

[1] Maritimes Forest Research Centre, Environment Canada, Fredericton, N.B.

INTRODUCTION

In New Brunswick operational spraying with preparations of B.t.k. took place in 1980, 1982, and 1983 to provide protection of balsam fir and spruce foliage on private woodlots. In 1980, all woodlots were sprayed with B.t., but in 1982 and 1983 only a small proportion of the woodlots were sprayed with B.t. Regulating agencies permitted the use of chemicals for woodlot protection in 1981, 1982, and 1983, but the stringent rules imposed on the chemical application applied equally as well to areas treated with B.t.

Historically, in New Brunswick there has been a continuing interest in the development and use of B.t. by the Canadian Forestry Service and Forest Protection Ltd. from 1960 to the present. These agencies have worked cooperatively in testing B.t. preparations as they became available and seemed to offer some promise for forest protection (Table 1).

The results of these tests added to the bank of knowledge on B.t., sometimes positively, sometimes negatively. It must be understood that through the 1970's and continuing into the '80s, there were many advances in the development of more stable and concentrated formulations of B.t. Consequently the B.t. formulations used in 1982 and 1983 are not the same as that used in 1980 or tested previously. One of the nagging problems, which has been identified by investigators in Canada and the USA, with currently available B.t. preparations is apparent inconsistent product potency and viscosity.

EFFICACY

Efficacy of B.t. and chemical sprays is determined by comparing prespray budworm population density, and post-treatment defoliation and pupal survival in treated and non-

treated areas. Figure 1 shows the relationship between pre-spray populations and resultant defoliation in nontreated control areas for 1980 and 1983.

1980. In 1980 (Table 1) about 10 521 ha were treated with either Thuricide 16B or Novabac-3 using three spray delivery systems - 1) fixed wing aircraft with boom and nozzle spray gear, 2) fixed wing aircraft with Micronair AU 3000 rotary atomizers, and 3) helicopter with boom and nozzle. Most spray blocks were rectangular woodlots and most could be easily identified from the air. The results of the operations are detailed by Steel (1982).

The results in terms of foliage protection were extremely variable depending on timing, aircraft type, forest composition and condition, and budworm population density. Of the 148 woodlots assessed, 50% had a detectable level of protection.

1982. In 1982 about 4 000 ha of forest were treated with B.t., 3 200 ha operationally with Dipel 88 and 800 ha in a test program with Novabac-3 and Bactospeine.

The area treated with Dipel 88 was located in northwestern New Brunswick. One-half of the area was treated at a rate of 20 BIU/ha and the other at 30 BIU/ha. The Dipel was sprayed "neat" as is in the drum. Results were good in terms of larval mortality, but poor in terms of foliage protection. This is an unresolved mystery.

The results of the trials with Novabac-3 and Bactospeine were encouraging; adequate foliage protection was provided at 30 BIU/ha. This information was used to complete the registration package for Novabac-3.

1983. Comments on this year's results are preliminary but show a trend similar to those of 1980. However unlike 1980 results, in 1983 it was possible to compare chemical and B.t. spraying at approximately the same timing and in the same geographical area (Tables 2, 3). Prespray populations of budworm were quite variable, but most of the B.t. blocks had substantially lower infestations than the chemical treatment areas.

About 10 117 ha were treated with Novabac-3 and the preliminary data (Table 2) show that 9 of the 17 areas sampled had a detectable level of foliage protection. Similarly, of the 17 chemical treatment blocks (Table 3), 9 had a detectable level of foliage protection.

This result in which only 53% of the treatment blocks sampled have a detectable level of foliage protection is probably due to factors other than efficacy of either B.t. or fenitrothion.

FACTORS AFFECTING B.t. PERFORMANCE

The major factors affecting performance of B.t. and chemical sprays applied to woodlots and similar forest areas are:

1. Irregular-shaped spray areas
   - Difficult to navigate and spray
   - Increased boundary zone compared with rectangular spray blocks.

2. Shut-offs inside treatment areas
   - As dictated by instructions, these areas included 1) cuts, 2) presence of people, 3) visible water, 4) non-susceptible forest type, and 5) roads. This results in

dilute spray application to the area, increase in boundary zone, and probable reduction in expected efficacy.

3. Forest composition and condition
   - Many of the areas selected for treatment have had a long history of budworm damage and a complex harvesting history. As a result, much of the forest is very heterogeneous in both species composition and age class distribution.
   - Budworm damage has been severe on many of the areas. As a result, surviving susceptible trees are in poor condition.
   - Because of these factors and highly variable spruce budworm larval populations between trees, assessment of efficacy is difficult.

4. Weather
   - Regulatory constraints i.e., low wind speed almost guarantees off-target drift hence reduction in deposit in target zone.
   - Rain: hours after spraying can reduce efficacy for B.t.
   - Relative humidity should be high for water-based B.t. sprays, for improved effect.

REFERENCES

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Table 1. Synopsis of B.t.k. use in New Brunswick 1960 to 1983

Year	B.t.	Area (ha)	Agencies	BIU /ha	Vol. L/ha	Aircraft	Spray system	Results: Larval mortality	Results: Foliage protection
1960	Thuricide SO 75	35	CFS/FPL	-	14	Stearman	B&N	Poor	Poor
1962	Thuricide SO 75	20	CFS/FPL	-	14	Stearman	B&N	Poor	Poor
1969	Thuricide 90TS	120	CFS/FPL	-	14	Stearman	B&N	Marginal	Not measured
1975	Thuricide 16B	320	CFS/FPL	20	7	Cessna AgTruck	Micronair	Excellent	Fair
	Dipel	400	CFS/FPL	20	7	AgTruck	Micronair	Excellent	Fair
1979	Thuricide 16B	200	CFS/FPL	20	7	AgCat	B&N	Variable	Poor
	Dipel	40	CFS/FPL	20	4	AgTruck	Micronair	Excellent	Good
1980	Thuricide 16B					Small Ag	B&N &	Variable	Variable
	Novabac 3	10 521	FPL	20	7	aircraft	Micronair		
1982	Dipel 88	1 600	FPL	20	1	AgCat	Micronair	Excellent	Poor
		1 600	FPL	30	1.5	AgCat	Micronair	Excellent	Poor
	Novabac 3	400	CFS/FPL	30	7	AgCat	Micronair	Good	Fair
	Bactospeine	200	CFS/FPL	30	7	AgCat	Micronair	Good	Fair
		100	CFS/FPL	30	4.7	AgCat	Micronair	Good	Fair
		100	CFS/FPL	15	2.4	AgCat	Micronair	Fair	Poor
1983	Novabac-310	10 117	FPL/DNR	30	4.7	Ag-aircraft	Micronair	Variable	Variable
	Futura 11	40	CFS/FPL	30	1.1	AgTruck	Micronair	Excellent	Excellent
	Dipel 176	40	CFS/FPL	30	0.7	AgTruck	Micronair	Good	Fair

CFS - Canadian Forestry Service FPL - Forest Protection Ltd. B&N - boom and nozzle
BIU - Billion International Units

Table 2. Summary of the results of spraying B.t.k. on woodlots (balsam fir) for 17 spray areas in 1983.

Development		Prespray	Defoliation		% foliage saved
Shoots	Larvae	larvae/branch	Observed	Expected	
3.1	3.4	1.5	60	5	0
		5.0	70	30	0
		5.0	80	30	0
3.4	3.4	13.0	100	70	0
		7.0	100	50	0
		5.0	10	30	20
		10.0	20	60	40
3.9	3.5	3.0	60	15	0
		5.0	60	30	0
		22.0	10	90	80
3.9	3.6	8.0	60	55	0
4.0	3.5	12.0	30	70	40
		18.0	30	85	55
4.4	3.8	5.0	10	30	20
		11.0	50	65	15
4.6	3.0	6.8	30	45	15
4.9	3.3	6.8	25	45	20

Table 3. Summary of the results of spraying Fenitrothion on woodlots (balsam fir) for 17 spray areas in 1983.

Development		Prespray larvae/branch	Defoliation		% foliage saved
Shoots	Larvae		Observed	Expected	
1.0	3.0	19	70	85	15
2.4	3.1	11	70	65	0
		19	70	85	15
2.6	2.8	25	80	100	20
2.7	3.3	6	40	40	0
2.8	2.8	15	90	75	0
2.9	3.3	7	90	50	0
		8	40	55	15
		16	40	80	40
		22	40	90	50
		24	100	100	0
		32	100	100	0
3.0	2.9	3	80	15	0
		14	20	75	55
3.1	3.4	25	100	100	0
4.6	3.0	12	40	70	30
4.9	3.3	9	40	60	20

Table 4. Comparison of 1983 spraying with Novabac-3 and Fenitrothion emulsion, pooled data, 17 sets of data per treatment.

Treatment	Prespray larvae/branch	Defoliation %		Average development	
		Observed	Expected	Shoots	Larvae
Novabac-3	8.7	50	50	3.4	3.3
Fenitrothion	16.4	60	75	2.7	3.1

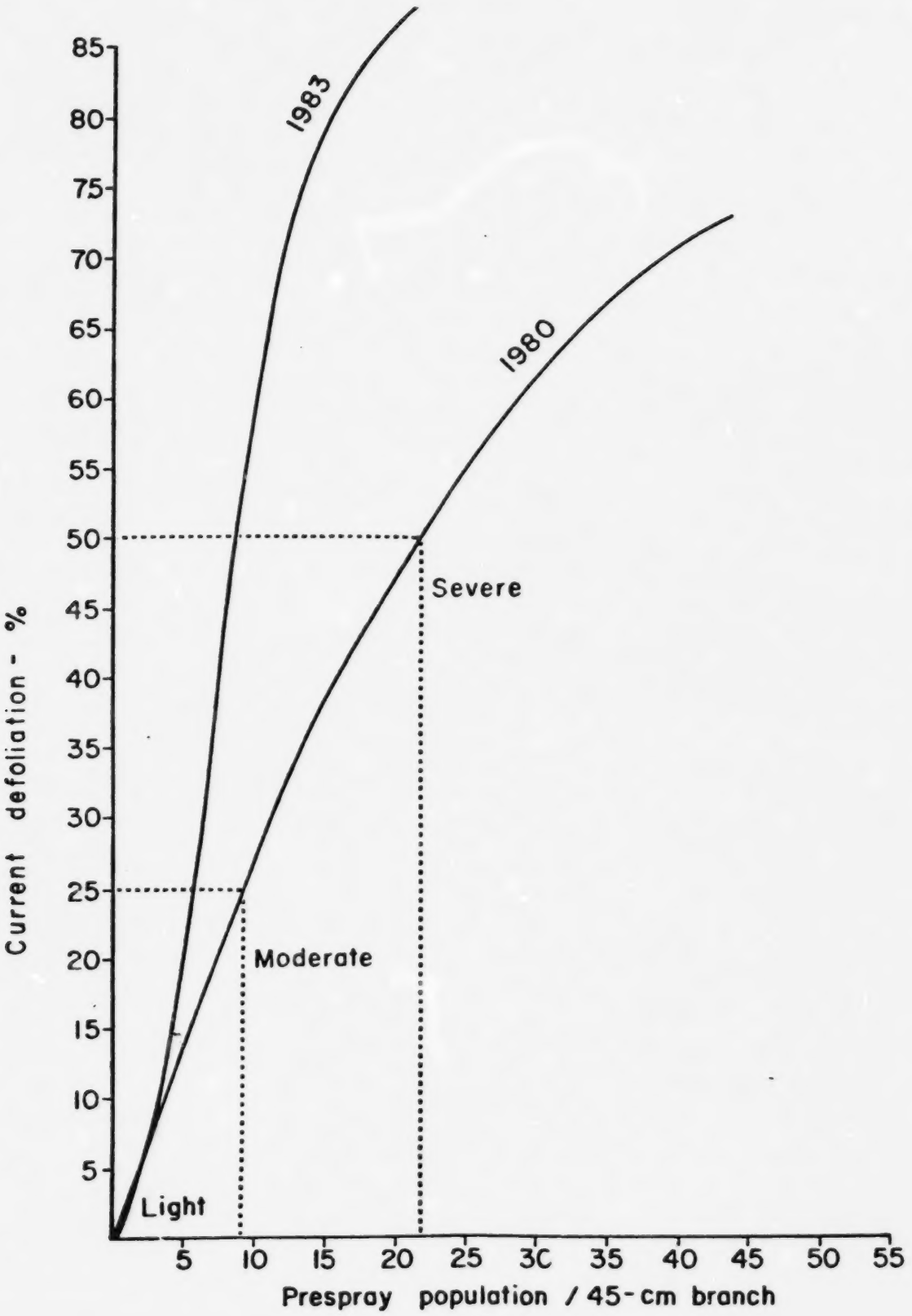


Figure 1: Relationship between prespray budworm population and current defoliation for balsam fir control data.

OPERATIONAL USE OF BACILLUS THURINGIENSIS KURSTAKI AGAINST SPRUCE BUDWORM IN NOVA SCOTIA 1980-1983

DR. T.D. SMITH[1]

[1] Nova Scotia Department of Lands & Forests

INTRODUCTION

Nova Scotia has a unique mixture of forest, agriculture, and marine use patterns and often all three can be found on the same farm. The forests of Nova Scotia are both susceptible and/or vulnerable to feeding by the spruce budworm. The degree of vulnerability has been reflected by the host species involved, with balsam fir suffering the most. The spruce budworm confined its devastation to the Nova Scotia Highlands and adjacent areas on both the Mainland and Cape Breton. An estimated total loss to date is 24 x 10^6 m^3 of wood.

FOLIAGE PROTECTION

Foliage protection efforts in Nova Scotia had an interrupted history. The first experimental program was in 1927 and the second in 1979. The operational program began in 1980. The general magnitude of the operational programs is presented in Table 1.

In 1982 the emphasis changed from foliage protection of balsam fir on Cape Breton to that for red spruce on the Mainland. The estimated cost to protect red spruce in Nova Scotia is approximately one-third greater than balsam fir.

A. Aircraft

Ag-cats are used as spray aircraft and Cessna 172 are used as guidance aircraft. Total aircraft cost (Table 2), spray aircraft costs (Table 3), and guidance aircraft costs (Table 4), associated costs such as fuel and others (Table 5), and airport rentals (Table 6) are as follows.

Table 1. Overview of operational B.t.k. programs, Nova Scotia 1980-1983.

Year	Area (ha)	Total Cost ($ million)	Cost per hectare ($)[1]
1980	25 670	1.18	45.79
1981	30 752.4	1.10	35.54
1982	19 153.2	0.75	39.12
1983	20 726.5	0.75	35.22

Table 2. Total aircraft cost for B.t.k. programs, Nova Scotia, 1980-1983.

Year	Cost ($000)	Cost per hectare ($)
1980	380	14.79
1981	437	14.21
1982	320	16.71
1983	364	17.54

Table 3. Spray aircraft cost for B.t.k. programs, Nova Scotia, 1980-1983.

Year	Cost ($000)	Cost per hectare ($)
1980	310	12.08
1981	337	10.96
1982	263	13.77
1983	297	14.33

[1] Per hectare flown.

Table 4. Guidance aircraft cost for B.t.k. programs, Nova Scotia, 1980-1983.

Year	Cost ($000)	Cost per hectare ($)
1980	45	1.75
1981	71	2.31
1982	43	2.25
1983	48	2.23

Table 5. Fuel and associated cost for B.t.k. programs, Nova Scotia, 1980-1983.

Year	Cost ($000)	Cost per hectare ($)
1980	19	1.59
1981	21	1.93
1982	6	0.30
1983	12	0.61

Table 6. Cost of rental of Sargent's Airport at Parrsboro, Nova Scotia, 1980-1983.

Year	Rental Fee ($000)	Cost per hectare ($)
1980	6.0	0.23
1981	7.5	0.24[1]
1982	7.5	0.39
1983	7.7	0.37

[1] Upgrading of Crowdis Mountain Airport $180,000.00

B. Biocide

Commercial preparations of B.t.k. are not cheap. The price to the Province however, has declined during the past few years. The B.t.k. purchased in one financial year is paid from that year's budget. Unfortunately due to unforseen events, such as unfavourable weather for spraying and new environmental constraints, some B.t.k. gets carried over to the next year. This carry over tends to distort the actual per unit area cost for that year. Both values are presented in Table 7.

The general trend of decrease in cost of B.t.k. is reflected in both purchase price (Table 7) and application cost. The cost expressed on a BIU basis can also reflect the change in purchase price of B.t.k. (Table 8).

Table 7. Cost of B.t.k. by budget and use-year, B.t.k. programs, Nova Scotia, 1980-1983.

Year		Cost ($000)	Cost per hectare ($)
1980	Budget	382	14.89
	Use	382	
1981	Budget	267	8.69
	Use	237	7.73
1982	Budget	176	9.71
	Use	152	7.94
1983	Budget	77	3.72
	Use	130	6.30

Table 8. Comparison of purchase and total cost for B.t.k. program, Nova Scotia, 1980-1983.

Year	Biocide	Cost		Total Program Cost		B.t.k. Cost	
		$/L	$/BIU	$/ha	$/ha/BIU	$/ha	$/ha/BIU
1980	Thuricide 16B	2.84	0.68	45.79	2.90	14.87	0.74
1981	Thuricide 16B	2.41	0.57				
	Dipel 88	5.55	0.66				
	Total			35.54	1.78	7.73	0.39
1982	Thuricide 16B	2.41	0.57				
	Dipel 88	5.55	0.66				
	Thuricide 32LV	3.79	0.45				
	Total			39.12	1.96	7.94	0.40
1983	Dipel 88	5.55	0.66				
	Thuricide 32LV	3.79	0.45				
	Novabac-3	2.60	0.30				
	Total			36.10	1.80	6.30	0.32

C. Relative foliage protection

The efficacy of B.t.k. against the spruce budworm larvae has been mixed. There have been several interesting phenomena occur that tend to mask or invalidate the statistical anlysis of foliage protection and/or larval mortality. In 1981 the trees in the control areas in Cape Breton died. In 1982 there was a good seed year and most larvae stayed in the upper crown feeding on the flowers and ignored the foliage. The larval survival rate in 1982 was generally ten times that of 1981 i.e. from 1.0 to 4.0 in 1982 as compared to 0.1 to 0.4 in 1981. In 1983 there was a general decline of numbers throughout Mainland Nova Scotia. While the larval mortality was high, little foliage appeared to be saved as those larvae in the unsprayed area failed to consume the expected volume of foliage (Table 9).

Table 9. Relative foliage protection, B.t.k. programs, Nova Scotia, 1980-1983.

Tree Species	Use	% Foliage Protection[1] 1980	1981	1982	1983[3]
Balsam Fir	Timber	96-79	71	43	22
White Spruce	Cone Production	62	+ve[2]	+ve[2]	14-54
Black Spruce	Cone Production	74	+ve[2]	+ve[2]	+ve[2]
Red Spruce Species Complex	Timber	64-88	65-77	25-55	6-50

[1] % protection=$\frac{\text{\% defoliation check - \% defoliation spray}}{\text{\%defoliation check}} \times 100$

[2] Small areas $\leq$ 150 ha usually not monitored.

[3] General population decline through Nova Scotia in 1983.

ENVIRONMENTAL RESTRICTIONS

In Nova Scotia the forest owner can select any of the federally registered pesticides to suppress spruce budworm numbers. The following are the environmental restrictions that the proponent is responsible to adhere to:

1. Spills (local) - B.t.k. composted and if necessary clean up area.

2. Area boundaries - in the absence of distinctive topographic features the boundaries of the proposed treatment area must be flagged.

3. Pilots are not to handle or help load aircraft.

4. Application - restrictions

   (a) Wind $\leq$ 8 km/hr

   (b) RH = 60-95%

   (c) No rain expected for 3-6 hours

   (d) No heavy dew on trees

   (e) No surface water body may become contaminated

   (f) Within 300 meters, measured horizontally of prescribed water shed area or so designated

   (g) Within 1.5 km, measured horizontally, of any municipal water supply lake, river or reservoir

   (h) Within 60 meters, measured horizontally of an individual potable supply

   (i) Within 30 meters, measured horizontally, from a public road, unless for weed control

   (j) Spraying must not be conducted at temperatures above 32°C

With respect to the following practices, provincial environmental regulations are equally restrictive for B.t. and for chemical pesticides:

   (a) filling of spray tanks from ground water supplies

   (b) flushing of sprayers

   (c) handling, use and disposal of containers

   (d) storage

OPERATIONAL USE OF B.T. IN MAINE
PART 1. EFFICACY

H. TRIAL JR. [1]

[1] Maine Forest Service, Augusta, Maine

INTRODUCTION

Maine has used B.t. as part of its operational spray project since 1979, and in the years since 1980, B.t. has been used on significant acreage. The trend in B.t. usage in Maine has been toward an acreage increase, but this increase has been slow. B.t. spray acreage and B.t. percentage of the total operation for the years 1979 to 1983 are as follows:

Year	Acreage	Percentage of Operation
1979	62,000	2
1980	200,000	15
1981	126,500	11
1982	89,000	10
1983	119,228	14

B.t. usage in Maine has generally been as a specialty insecticide used in specific operational situations. Before 1983 B.t. was not generally used where trees were classed in critical condition. In 1982 and 1983, however, B.t. was used in many areas of high or extreme budworm population. B.t. is often placed in areas of high human habitation and in areas of designated environmental hazard. B.t. has also been chosen for use in very wet areas to avoid poor spray coverage due to buffering policies with chemical insecticides. Recently B.t. has been the insecticide of choice in some areas of high red spruce concentration.

Many B.t. formulations, dosage, emission rates, and spray aircraft have been used since 1979. Prior to 1981, all operational treatments were made at the 8 BIU per acre rate and at volumes of 80 to 128 ounces per acre. Applications in 1979 were made with small agricultural fixed wing aircraft.

Most treatments in the years 1980 to 1982 were done with large jet (Bell 205, 212) helicopters. Testing done in 1982 led to a return to small agricultural aircraft in 1983, but these aircraft were equipped with rotary atomizers rather than the boom and nozzle systems used on small planes in 1979.

Tests in 1981 and satisfactory operational results in 1982 and 1983 have led to general acceptance of a 12 BIU per acre dosage for operational B.t. applications in Maine. The 12 BIU rate has resulted in consistent good B.t. results in Maine in the years 1981 to 1983.

Work in 1983 was oriented toward volume reductions in operational B.t. usage. Successful treatments in 1983 were made with 64 ounces or less total spray volume. Rotary atomizers are considered important in volume reducing efforts in Maine. Another important factor in Maine's effort in volume reduction has been the registration of highly concentrated B.t. products.

Several operational treatments were made in 1983 using undiluted B.t. products at volumes of 32 or 48 ounces. Results of these treatments were very satisfactory.

As mentioned earlier, many material and spray regimes have been used operationally in Maine in recent years. Rather than describe this wide variety of applications and attempt to discuss the efficacy of each, tables of trials made and results seen are provided in the form of tables extracted from the various annual project reports. Discussion of methods and efficacy will be limited to results considered important in the Maine experience.

EFFICACY

Results of B.t. application for 1981 through 1983 are shown in Tables 1 through 3 respectively.

Results of 8 BIU B.t. applications using Thuricide 16B and Dipel 4L at spray volumes of 80 to 128 ounces per acre were erratic in 1979 and 1980. Results in blocks evaluated ranged from 40% of expected defoliation in the best blocks to 90% of expected defoliation in the least effective treatments. Poor results were most often associated with cool or wet weather just before or immediately after spraying. However, each year had poor spray results in some chemical blocks for no apparent reason. Spray deposition in 1979 was often erratic, but applications made with large jet helicopters in 1980 were more consistent.

In 1981 operational applications of 8, 12, and 16 BIU per acre were made under comparable conditions. As in 1979 and 1980, 8 BIU treatments had variable results. Defoliation ranged from 50% of expected in the best areas to near 90% of expected defoliation in the worst areas. Under similar spray conditions, but higher populations, 12 BIU applications had 50% or less of expected defoliation. The best 12 BIU blocks had only 25% of expected defoliation. A split application of 16 BIU (8 + 8) gave about 50% of the expected defoliation level.

The observation was made in 1981 that larval mortality occurred much more rapidly in 12 BIU blocks than in 8 BIU blocks. Also, 12 BIU treatments in 1981 were the first B.t. treatments in Maine which were considered as effective and consistent as chemical application. In many cases protection on red spruce was better in 12 BIU B.t. areas than in chemical spray blocks.

Table 1. Results of B.t. treatment for the 1981 Maine spruce budworm control project.

Treatment	Area	Host[2]	% Population Control	% Defoliation	% Foliage Saved
DIPEL 4L					
8 BIU in 80 oz.	Block 18-1	F	56.7	87	13
		S	0.0	36	2
	Blocks 13-8, 13-7, 12-2	F	0.0	61	32
	West 22-16	F	95.0	58	30
		S	86.3	13	25
	Southwest	F	87.2	14	14
		S	81.4	12	10
THURICIDE					
8 BIU in 80 oz.	Block 18-2	F	0.0	71	29
		S	0.0	18	20
DIPEL					
12 BIU in 120 oz.	Block 17-1	F	28.7	(24)34[1]	31
	Spruce Protection	S	25.3	(18)24	14
	5 Plate	F	89.4	31	61
		S	55.7	23	58
THURICIDE					
12 BIU of 24B	7 Plate	F	16.1	26	60
in 96 oz.		S	0.0	22	43
DIPEL					
16 BIU 8 + 8	5 Plate	F	82.3	50	42
in 80 oz.		S	80.7	17	28

[1] Number in () represents omitting of a sample line which received heavy rain shortly after spray.

[2] F = fir; S = spruce

Table 2. Results of B.t. treatment for the 1982 Maine spruce budworm control project.

Treatment	Area	Host	% Population Control	% Defoliation	% Foliage Saved
DIPEL 4L					
12 BIU in 120 oz. Helicopter	M72, 73, 74 Narraguagus River Area, T34 MD	F	85.0	36.0	44.1
		S	70.3	28.7	22.3
12 BIU in 96 oz. Thrush/Micro.	J5 Long A	F	96.3	10.7	25.1
		S	91.2	5.7	21.6
THURICIDE 32LV					
12 BIU in 96 oz. Thrush/Micro.	J5 Long A	F	95.5	17.3	18.5
		S	94.2	9.7	17.6
*BACTOSPIENE					
12 BIU in 96 oz. Helicopter	BI3 Stockholm	F	72.2	12.0	22.8
		S	55.3	8.0	21.5

* This area received rain within 4 hours of application.

Table 3. Results of B.t. treatment for the 1983 Maine spruce budworm control project.

Treatment	Area	Host	% Population Reduction	% Defoliation	% Foliage Saved
DIPEL 6L					
12 BIU in 64 oz.	G 46, Smyrna	F	73.0	47.1	25.7
		S	85.5	58.7	13.5
	M 82, M111; T26ED	F	93.6	44.6	43.6
		S	97.4	26.0	45.3
		H	89.3	34.1	33.8
	M 72, M 73; T34MD	F	81.3	12.3	18.1
	SMALL TREES	S	90.4	13.8	16.6
	M121	F	78.7	26.1	33.4
		S	79.7	20.0	41.6
		H	97.8	6.3	26.4
DIPEL 4L					
12 BIU in 48 oz.	M 5; Danforth	F	94.5	15.1	36.1
Undiluted		S	96.4	16.4	16.4
DIPEL 6L					
12 BIU in 32 oz.	M 10; Topsfield	F	87.5	28.4	22.8
Undiluted		S	86.6	20.9	11.9
THURICIDE 32 LV					
12 BIU in 64 oz.	G 26; T9R3	F	91.3	52.2	20.6
		S	97.4	34.1	38.1
	B 5; T17R5	F	88.6	45.6	27.0
		S	93.7	59.1	13.1
THURICIDE 32LV					
12 BIU in					
48 oz. Undiluted	B 13; Stockholm	F	85.4	56.9	34.3
		S	96.9	24.5	47.9
THURICIDE 24B					
12 BIU in 96 oz.	J 12; Medway	F	91.2	33.4	45.6
		S	91.8	13.1	38.0
BACTOSPIENE					
12 BIU in 64 oz.	G 27; T8R3	F	86.7	45.6	27.2
		S	81.9	42.8	29.4

One block treated in 1981 was sprayed with 12 BIU Dipel 4L before larvae entered spruce buds (index 3.5). This timing was several days earlier than normal B.t. timing in Maine. Results on spruce were about the same as later timing.

Excellent spray deposit was achieved in 1981 with large jet helicopters. Many blocks had in excess of 50 droplets per cm^2.

In 1982 all treatments were made at the 12 BIU rate. All treatments had 50% or less of expected defoliation and were considered very successful. Results were good on red spruce.

Comparisons were made between Dipel 4L, Thuricide 32 LV, and Bactospiene in 1982. The Bactospiene block had inconsistent results due to heavy rain after treatment. Dipel and Thuricide were considered equal in terms of efficacy.

Spray deposit was compared between Micronair-equipped Thrush aircraft and jet helicopters. Spray deposit was comparable with both aircraft. Deposit and results were also comparable with 120 and 96 oz. applications.

The 1983 operation had variable results due to high populations and difficult weather, but most 12 BIU B.t. blocks had good results. Most blocks had 50% or less defoliation. B.t. products produced some of the better red spruce results for the entire project. Good spray deposit was obtained with Micronair equipped Thrushes. All applications were done with 64 oz. or less volume. Efficacy of all materials used was comparable.

Several blocks were treated operationally with undiluted B.t. products. Dipel 6L was applied at 32 oz. and Dipel 4L and Thuricide 32LV were applied at 48 oz. All these treatments gave results comparable or better than 64 oz. applications.

All B.t. applications in Maine have been single applications with the exception of one 16 BIU (8 + 8) split application in 1981. B.t. is generally applied at the peak of the 4th larval instar on fir (index 3.7 to 4.2) and when a foliar target exists (index 3.5 to 4.0). Some applications have been made with an early timing in an attempt to get better spruce efficacy (before larvae enter spruce buds; larval index 3.2 to 3.5). B.t. has been effective at all planned timings and during any larval instar from 3rd to early 6th. Late timing results in more pre-spray defoliation.

CONCLUSIONS

Generally, B.t. has worked better on red spruce than on fir, but fir results are usually comparable to chemical results.

Conclusions regarding the efficacy of B.t. in Maine from 1980 through 1983 are as follows:

1. All treatments are made at the 12 BIU rate due to variability experienced with 8 BIU compared to consistent good results with 12 BIU.

2. Concentrated B.t. products are preferred and no significant differences have been shown between Dipel or Thuricide products. Bactospiene has been used on a small scale, but trials suffered from application and weather problems in 1982 and 1983 and results were inconclusive.

3. Applications at 64 oz. gave good deposit as did all undiluted applications. B.t. applications will be made at low volume and probably undiluted in the future.

4. Rotary atomizers are preferred to boom and nozzle systems. Small droplets are preferred (100 microns).

5. Currently B.t. is used against any population level in Maine.

6. Since the initiation of the 12 BIU rate and improved application techniques, B.t. results have been comparable to chemical results. Results on spruce are better than results on fir. B.t. applications seem to be more sensitive to marginal operational weather, especially when cool or wet weather makes larvae inactive shortly after spraying.

OPERATIONAL USE OF B.T. IN MAINE
PART 2. COST, OPERATIONAL CONSIDERATIONS AND ENVIRONMENTAL CONSTRAINTS

T. MORRISON [1]

[1] Maine Forest Service, Augusta, Maine

COST

The cost figures that follow (Table 1) include: insecticide, aerial application, mixing and loading. Concentrations (BIU's per gallon/litre) of B.t. products employed by the Maine Forest Service have increased over the last four years. This has allowed for a reduction in the total spray volume per acre needed to achieve a desired BIU per acre rate. Reducing the finish spray volume per acre has reduced application costs. Application costs have also been reduced by employing fixed wing aircraft for B.t. applications rather than the more expensive rotary wing aircraft.

AIRCRAFT AND SPRAY SYSTEM

Over the last four years, the Maine Forest Service has progressed from rotary wing aircraft equipped with conventional boom and nozzle (flat fan 8006) to fixed wing aircraft equipped with rotary atomizers (Micronairs, 45° setting). Rotary wing aircraft were used initially to obtain adequate deposit and to more accurately target spray. However, agricultural fixed wing aircraft, like the Thrush and Airtractor, are comparable to rotary wing aircraft in their ability to target spray and can achieve adequate deposit when equipped with rotary atomizers. By making these changes, we have been able to maintain effective spray deposit (20 drops/cm^2) while reducing operational costs.

MIXING AND LOADING

There are time limitations for holding B.t. formulations once mixed with water. These vary from 24 to 72 hours, depending on the product. If mixed improperly by placing B.t. in the mix tank first and then adding water, Dipel products can produce an invert emulsion. Many of the B.t. products are incompatible with each other, requiring a thorough flushing between material changes. Some of the B.t. products,

especially Thuricide 32LV, are heavier than the chemical insecticides. Depending on aircraft and airstrip limitations, this can cause a reduction in gallons (litres) per load. Our experience with undiluted formulations has been favorable and most likely our 1984 B.t. operation will be entirely at the undiluted rates. This will eliminate mixing and holding problems and reduce application costs.

OCCUPATIONAL SAFETY

Although B.t. products are non-toxic to humans, label statements do call for precautions to avoid contact with eyes, open wounds, and skin. Immediate flushing with water is recommended. Compared with the chemical insecticides presently used in our program, limited safety measures are necessary.

WEATHER GUIDELINES

Guidelines for application of B.t. products are more stringent then those recommended for oil base insecticides. We aim for at least four hours separation (daylight hours) between end of spray and any anticipated rainfall. No spraying is carried out during evening period if rainfall is expected before dawn. When temperatures exceed 70°F, at least 60% relative humidity is necessary to spray.

ENVIRONMENTAL CONSTRAINTS

Buffer zones are not required by regulatory agencies for B.t. The limited buffer zones adhered to by the Maine Forest Service are self-imposed (Table 2). Due to the relatively safe nature of B.t. with regard to aquatic organisms and humans, attempts are made to schedule B.t. on blocks where water or permanent human habitation would make effective treatment difficult if a chemical insecticide with appropriate buffers were employed. Spray systems are shut off when passing directly over water as an insecticide saving measure.

CONCLUSIONS

Substantial cost reductions have been achieved over the last four years in the operational use of B.t. in Maine. These cost savings are primarily due to higher potency materials, lower finish spray volumes, and aircraft changes in our program. The cost per BIU has decreased from approximately $0.62/BIU in 1980 to $0.33 in 1984. It is highly unlikely, however, that cost reductions of the same magnitude will be possible over the next few years. At the present time, chemical insecticide application costs are approximately 40% less than B.t. application costs. Undiluted applications will help make B.t. costs somewhat more competitive with chemical insecticide costs, however.

Table 1. Maine Forest Service operational B.t. rates and costs 1980-1983.

	PRODUCT (name) BIU/gal. (BIU/L)	ACTIVE INGREDIENT BIU/ac	(BIU/ha)	FORMULATION RATE oz./ac	(L/ha)	gallons	(litres)	COST (U.S. DOLLARS) Fixed Wing* acre	(hectare)	Rotary Wing* acre	(hectare)
1980	Thuricide 16B 16 (4.2)	8	(20)	80	(5.85)	9.00	(2.37)	10.07	(24.87)	10.20	(25.19)
				128	(9.35)			12.66	(31.27)	12.86	(31.76)
	Dipel 4L 32 (8.4)	8	(20)	80	(5.85)	19.75	(5.20)	10.51	(25.96)	10.64	(26.28)
1981	Thuricide 16B 16 (4.2)	8	(20)	80	(5.85)	10.40	(2.74)	8.75	(21.61)	9.69	(23.93)
	Thuricide 24B 24 (6.3)	12	(30)	96	(7.02)	15.60	(4.11)	11.77	(29.07)	12.89	(31.84)
	Dipel 4L 32 (8.4)	8	(20)	80	(5.85)	15.28	(4.02)	7.37	(18.20)	8.31	(20.53)
		12	(30)	120	(8.77)			10.32	(25.49)	11.73	(28.97)
		8+8	(20+20)	80+80	(5.85+5.85)			13.25	(32.73)	15.13	(37.37)
1982	Thuricide 24B 24 (6.3)	12	(30)	96	(7.02)	9.00	(2.37)	10.95	(27.05)	12.90	(31.86)
	Thuricide 32LV 32 (8.4)	12	(30)	96	(7.02)	12.00	(3.16)	10.95	(27.05)	12.90	(31.86)
	Dipel 4L 32 (8.4)	12	(30)	96	(7.02)	14.88	(3.92)	12.03	(29.71)	13.98	(34.31)
				120	(8.77)			13.52	(33.39)	15.96	(39.42)
	Bactospeine 35 (9.2)	12	(30)	96	(7.02)	16.42	(4.32)	12.00	(29.64)	14.03	(34.65)
1983	Thuricide 24B 24 (6.3)	12	(30)	96	(7.02)	9.00	(2.37)	8.71	(21.51)		
	Thuricide 32LV 32 (8.4)	12	(30)	64	(4.68)	10.45	(2.75)	6.82	(16.85)		
				**48	(3.51)			6.17	(15.24)		
	Dipel 4L 32 (8.4)	12	(30)	**48	(3.51)	14.88	(3.92)	7.83	(19.34)		
	Dipel 6L 48 (12.6)	12	(30)	64	(4.68)	17.48	(4.60)	7.27	(17.96)		
				**32	(2.34)			5.96	(14.72)		
	Bactospeine 35 (9.2)	12	(30)	64	(4.68)	10.75	(2.83)	6.58	(16.25)		

* Cost figures for fixed wing and rotary wing include insecticide, aerial application, mixing and loading.
** Undiluted Rate.

Table 2. Buffer Zones for Insecticide Application - Maine Spruce Budworm Spraying.

	Single Engine Aircraft			Multi-Engine Aircraft	
Terrestrial:	Sevin-4-Oil, Sevin FR	Other Chemical [1] Insecticides	B.t. formulation	Sevin-4-Oil, Sevin FR	Other Chemical [1] Insecticides
Permanent human habitation[2]	½ mile	½ mile	none	1 mile	1 mile
Publically maintained roads[3]	500 ft.	500 ft.	500 ft.	500 ft.	500 ft.
Apiaries	½ mile	½ mile	none	1 mile	1 mile
Organic farms	½ mile	½ mile	none	1 mile	1 mile
Eagle nesting sites	½ mile	½ mile	½ mile	½ mile	½mile
Blueberry production areas	½ mile	½ mile	none	1 mile	1 mile

Aquatic:	Sevin-4-Oil, Sevin FR	Other Chemical Insecticides	B.t. formulation	Sevin-4-Oil, Sevin FR	Other Chemical Insecticides
Critical fisheries	500 ft.	150 ft.	none	1,000 ft.	300 ft.
Marine and estuarine waters	½ mile	½ mile	none	1 mile	1 mile
Other waters[4]	250 ft.	150 ft.	none	500 ft.	300 ft.
Municipal water supply intakes	1 mile	1 mile	none	1 mile	1 mile

[1] Other chemical insecticides include Orthene Forest Spray, Orthene Specialty Concentrate, Matacil 180 Flowable, and Zectran.

[2] Permanent human habitation-includes permanent dwellings, schools, churches, and occupied business.

[3] Publically maintained roads-applies to any roads which are maintained with public funds. Buffer zones may be eliminated if persons are stopped and warned during spraying and if no human habitation as defined in note 2 is present.

[4] Other waters-includes rivers, streams, ponds, lakes, and ephemeral streams and ponds with flowing or standing water visible from an aircraft flying at an altitude of 1,000' above the terrain.

OPERATIONAL USE OF B.T. IN MAINE
PART 3. INDUSTRY EXPERIENCE

J.R. WILLIAMS [1]

[1] International Paper Co., Augusta, Maine

BACKGROUND

International Paper Company for the last several years has provided aerial spray treatment of insecticide to protect spruce-fir foliage in Northern Maine from the spruce budworm, treating an average of 75,000 to 100,000 acres per year. Protection has been part of the State-conducted Maine Forest Service program and involved the use of chemicals only. The State's program prohibited the use of chemicals in sensitive areas around water courses or water bodies, and created large untreated buffers within spray treatment areas. The general tree condition within treated areas was much better than in the non-treated areas, and included some scattered mortality but not a significant reduction to the growing stock. The buffer areas, untreated, were in poor condition; often the areas adjacent to these buffers were also in a similar condition. This may be a result of the applicator's buffering buffers to avoid violation of environmental regulations.

In January of 1983 IP decided to conduct its own spray treatment program to provide protection best meeting IP management objectives. This included protecting the buffer areas around the water courses within spray blocks to:

1. Provide foliage protection to fir, primarily and spruce, secondarily.
2. Retard development of stand mortality.
3. Reduce the population source within the treated areas to reduce reinfestation.

To meet these objectives, there were two options of insecticide use:

1. A project of 100% Bacillus thuringiensis (B.t.).
2. A project integrating chemicals and B.t.

This is the first large-scale aerial insecticide application project to be undertaken by IP in the Northeast. We had to develop, from point zero, a program plan and budget.

Program development included many informal discussions with researchers, users, and manufacturers' representatives about the B.t. options available. Enventually these discussions focused on the possible options to reduce the high cost associated with B.t. applications that have restricted its use. While there were no conclusive, hard scientific research results to support the use of B.t. applied neat or undiluted at 12 BIU per acre, we thought that this application would work and would both simplify our program and reduce the B.t. costs.

We then designed a program where areas within 600 feet of streams or standing waterbodies, or within areas frequently involved with human occupation or without controlled access were identified for treatment with B.t. The remaining less sensitive areas were slated for treatment with chemicals. In a few instances the 600 feet was reduced to a minimum of 300 feet, in order to define treatable areas.

Block designs included input regarding the minimum swath width necessary for application. Frequently, this process left some blocks which were adjacent to a B.t. treatment block too small or impractical to treat with chemicals. These problem blocks were redesignated for treatment with B.t. This resulted in a spray treatment program of 100,000 acres, 36 percent to be treated with B.t. and 64 percent with chemicals. During budgeting and cost estimating, we recognized that B.t., even when applied neat, would still be significantly higher than the cost of the chemical insecticide Matacil.

Because larval populations exceeded 25 L2 per branch (mean of 60) as estimated by the Maine Forest Service within the spray treatment areas, historical assumptions indicated that B.t. might not be as effective as when used in more moderate populations; this assumption supported our decision to use chemicals in the less environmentally sensitive areas.

COST OF B.T.

Because of IP corporate sensitivity to proprietary cost information and government regulations, I will index cost estimates to publically available price quotations from the Maine Forest Service 1983 project or an estimate of industrial average for the area. Costs are presented in Table 1. Cost components are identified by unit as measured and carried on a per acre basis for comparison. The components are in U.S. funds and measure, and include:

Material - Insecticide - Quotations per gallon by suppliers to the Maine Forest Service 1983 program. B.t. @ $15.00/gal.; Matacil @ $15.50/gal.

Carrier - Diesel - $1.15/gal representing an estimate of supplier's annual rate for Red Pine location.

Aircraft - Estimated industry average of $4.75 per gallon for Red Pine area - to mix, load, and apply. Includes spray aircraft, monitor aircraft, guide aircraft, pilots, spotter and ground personnel. Spray aircraft are all single engine fixed wing capable of treating blocks generally located 8-30 miles from airstrip with about 20% of project located 45-75 miles ferry distance. This cost is variable and influenced by the logistics of each specific project.

Storage Tank - Estimated rental cost of trailer tanks (7,000 ± gal. capacity) at $125 per month plus $1,120 ea. for round trip transportation charges.

This is not our exact cost, but what one could reasonably expect for a project with similar conditions and goals. Thus, in addition to the basic cost of about $5.00 per acre, there are administration and support costs particular to the organization involved.

EFFICACY OF B.T.

In reviewing the results as determined by defoliation estimates of treated vs. untreated areas, we must remember that for most B.t. treated stands the foliage present for 1981 and 1982 was minimal and often completely lacking and the ability of the trees to produce new foliage was minimal. My perception is that without treatment three-quarters of the fir and one-half of the red spruce would be dead by the end of 1984. The treatment was, I believe, successful in that for both species defoliation was limited to 50% and bud loss, Fettes class 12, was reduced in spruce from 45% to 9%. Fir bud loss was estimated as 11% in treated vs. 15% in non-treated areas.

Defoliation observed in untreated areas was much higher than in treated acres. The average defoliation in unsprayed areas as determined by IP and used in Table 2 is derived from averaging surveys of untreated areas, including some stands that had much better foliage conditions prior to current year feeding due to past protection efforts than did the B.t. treated areas. Table 2 presents defoliation and protection results.

B.t. Application and Operational Considerations

B.t. selected for use in this project was DIPEL 6L.
Application volume - 32 ounces per acre (12 BIU).
Nozzles used - Micronair AU3000 rotary atomizer.
Aircraft used - PZL M18 DROMADER.
Application dates - June 11 - June 14.
Weather - Temperature 70's and 80's - thundershowers night of June 15th and again on 17th, then hot and humid.

The B.t. was delivered to the Red Pine Airstrip in bulk via two tractor trailer transports which were off-loaded into a pre-parked storage trailer at the loading site.

The timing of applications was at the peak fourth instar, a fir bud development index of 5, and a spruce bud development index of only 1 or 2. We timed the application for fir protection, with one exception -- a spruce protection block in the Lincoln, Maine area, where the instar was at least peak 5th and the spruce bud development index was 4-5.

The B.t. material DIPEL 6L was applied undiluted (neat) at 32 ounces per acre.

The application utilized the single engine PZL M18 Dromader aircraft. Two were used, each equipped with six Micronaire AU 3000 rotary atomizers. Generally, the applications utilized a team consisting of a guide plane, two spray planes and one monitor plane. Occasionally, only one spray plane and monitor plane would free-fly the small or meandering blocks. Swath width of application was 450 feet per aircraft.

The application contractor supplied a positive displacement pump, meter and necessary hose to load directly from storage tank into the aircraft hopper. The contractor also supplied all personnel necessary to load, store and apply the insecticide.

IP supplied an aerial monitor person to ensure contract compliance, and an operations director, as well as lodging, cookroom, cooks, fuel supply and security. Safety requirements were in accordance with IP policy, U.S. - O.S.H.A. and the Maine Department of Labour. Some of the loading site safety requirements and regulations could have been eliminated if chemicals were not utilized because the toxicity and danger to humans of B.t. is much less than chemicals. The on-site activity at the airport was reduced by not having to mix or dilute the material. Maximum savings were not realized because personnel were required on site during chemical use. B.t. can be stored in trailers outside diked areas and can be handled without the concern for toxicity associated with chemicals -- both points highly favorable to B.t.'s use.

ENVIRONMENTAL CONSTRAINTS

In Maine, chemical insecticides are very restricted near human habitation, water bodies and other sensitive areas. B.t. is not so restricted. Because of the non-restrictive condition, we selected B.t. for use in water-related chemical buffer areas and areas where human habitation access was foreseeable during spray activities. Most areas treated with B.t. would not have been treated if only chemicals were available. Thus, the protection achieved was the only protection available.

SUMMARY

In 1983, International Paper Company provided aerial application of chemical and biological insecticides to provide foliage protection from the spruce budworm. Of 100,000 acres protected in Northern Maine, 36,000 acres (36%) were treated with B.t. The results were acceptable and similar to those obtained in areas treated with chemicals. The B.t. was applied undiluted at a dosage of 12 BIU -- 32 ounces per acre total volume. Application was by fixed-wing aircraft, using rotary atomizers. Much of the area treated with B.t. could not be treated with chemicals due to environmental regulations and guidelines established and monitored by the Maine Pesticide Control Board. Cost of B.t. representative to our project specifications is approximately $5.00 per acre (U.S. funds), plus administrative and support costs. Perhaps the more meaningful cost evaluation should be on the protected unit -- the cord. At 15 cords per acre, the protection cost would be $.33 per cord.

Table 1. Spruce budworm suppression costs for 1983 Red Pine operation. (per acre costs in U.S. funds)[1]

Unit	32 oz. vol. B.t.	20 oz. vol. Twice Split Matacil	32 oz. vol. Single Matacil
Insecticide	$3.75	$1.38	$1.50
Carrier	-	.26	.18
Aircraft	1.19	1.56	1.25
Storage Tank	.05	.10	.10
Total Cost	$4.99	$3.20	$3.03
Percent treatment cost less than B.t. cost		36%	39%
Percent B.t. cost higher than treatment cost		56%	65%

[1] Costs do not include administration and support costs. Costs reflect average prevailing rates for materials, contractors, and supplies for the Red Pine area during 1983 and are not the actual IP costs.

Table 2. Defoliation results: 1983 Red Pine spruce budworm suppression project.

Species	Percent of Tips by Defoliation Class			IP Average Defoliation
	3-35% Light	45-65% Moderate	75-100% Heavy	
Spruce not sprayed	14%	6%	80%	85%
Spruce sprayed	48%	14%	38%	49%
Fir not sprayed	17%	10%	73%	76%
Fir sprayed	38%	7%	55%	50%

OVERVIEW

THE REALISTIC PERFORMANCE OF

BACILLUS THURINGIENSIS

W.A. SMIRNOFF

Because Dr. Smirnoff intends to publish the paper he presented at the seminar, it is not included in this Proceedings. However, copies may be obtained from Dr. Smirnoff, Laurentian Forest Research Centre, P.O. Box 3800, Ste. Foy, Quebec - G1V 4C7.

SUMMARY

J.R. Carrow

1. Cost

One of the main objectives of this seminar was to develop a concensus on the potential for expanded operational use of B.t. against spruce budworm. Of the four factors emphasized in this seminar - cost, effectiveness, environmental contraints and operational considerations - cost is the most difficult to bring into clear focus. However, one thing is clear - cost has been and still is, the major obstacle to significant expansion in the use of B.t.

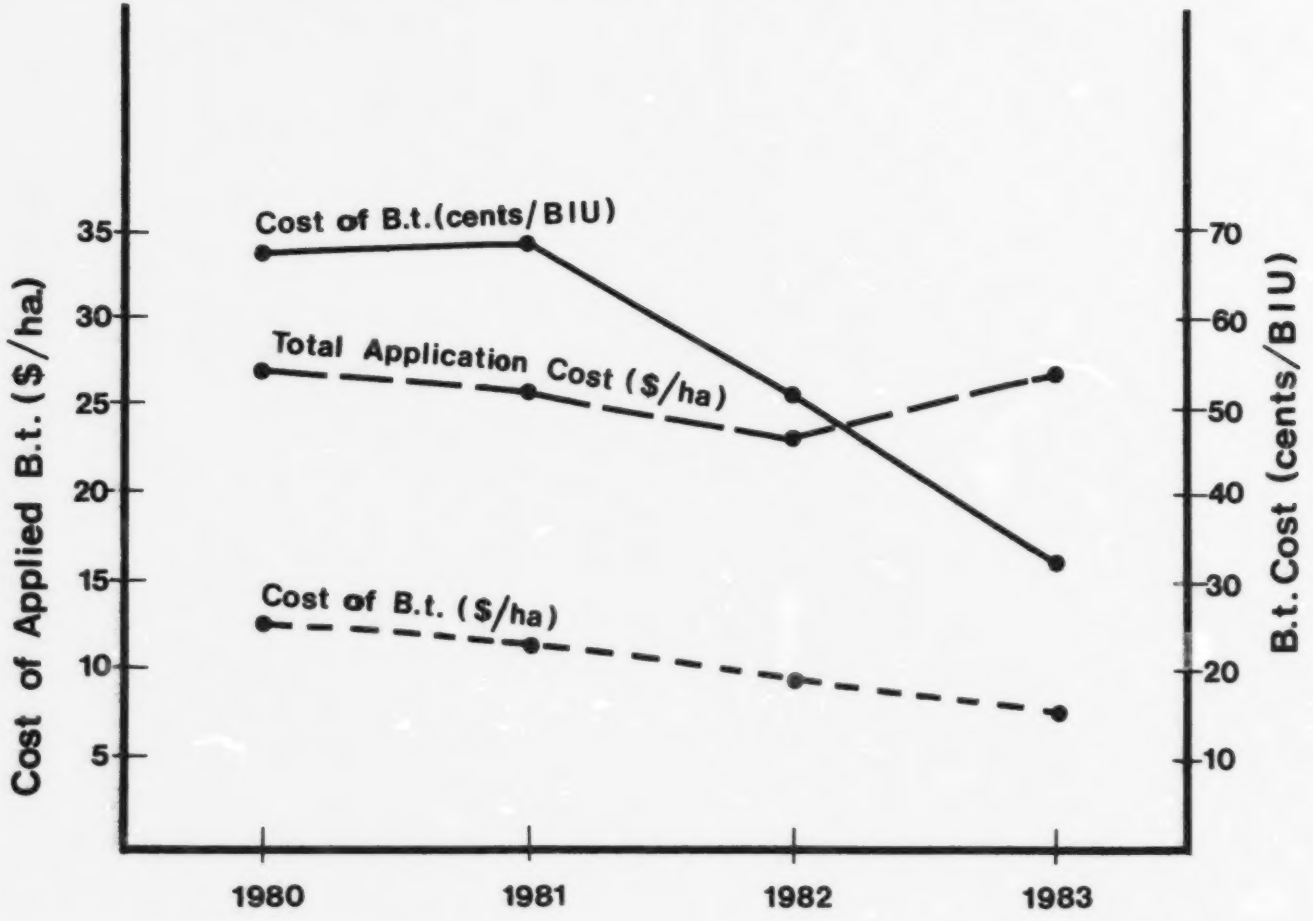
Of all the information presented at the seminar, cost data are clearly the most difficult to compare. However, the presentations did indicate which components of B.t. cost can be legitimately compared and why other components of cost vary so widely from one agency to another. Cost trends also become apparent.

The cost of B.t. products has declined significantly since 1980. Competitive bidding by the suppliers, combined with increasing use by Quebec, Ontario, Nova Scotia and Maine has forced the manufacturers to develop more cost-effective products. The workhorse B.t. formulation of a few years ago, Thuricide 16B, has given way to more concentrated products, resulting in lower unit cost, lower shipping cost and lower finished application volumes. Figure 1 illustrates the cost trends for three components of total cost - cost per BIU [1], cost of B.t. per hectare, and total cost of applied B.t. per hectare. Reductions in product cost have been steady and consistent geographically; the average cost per BIU has declined

[1] BIU - billion international units, the unit of active ingredient in B.t. products.

Figure 1

Costs of B.t. Application, 1980 to 1983 (averages of costs experienced by all agencies).



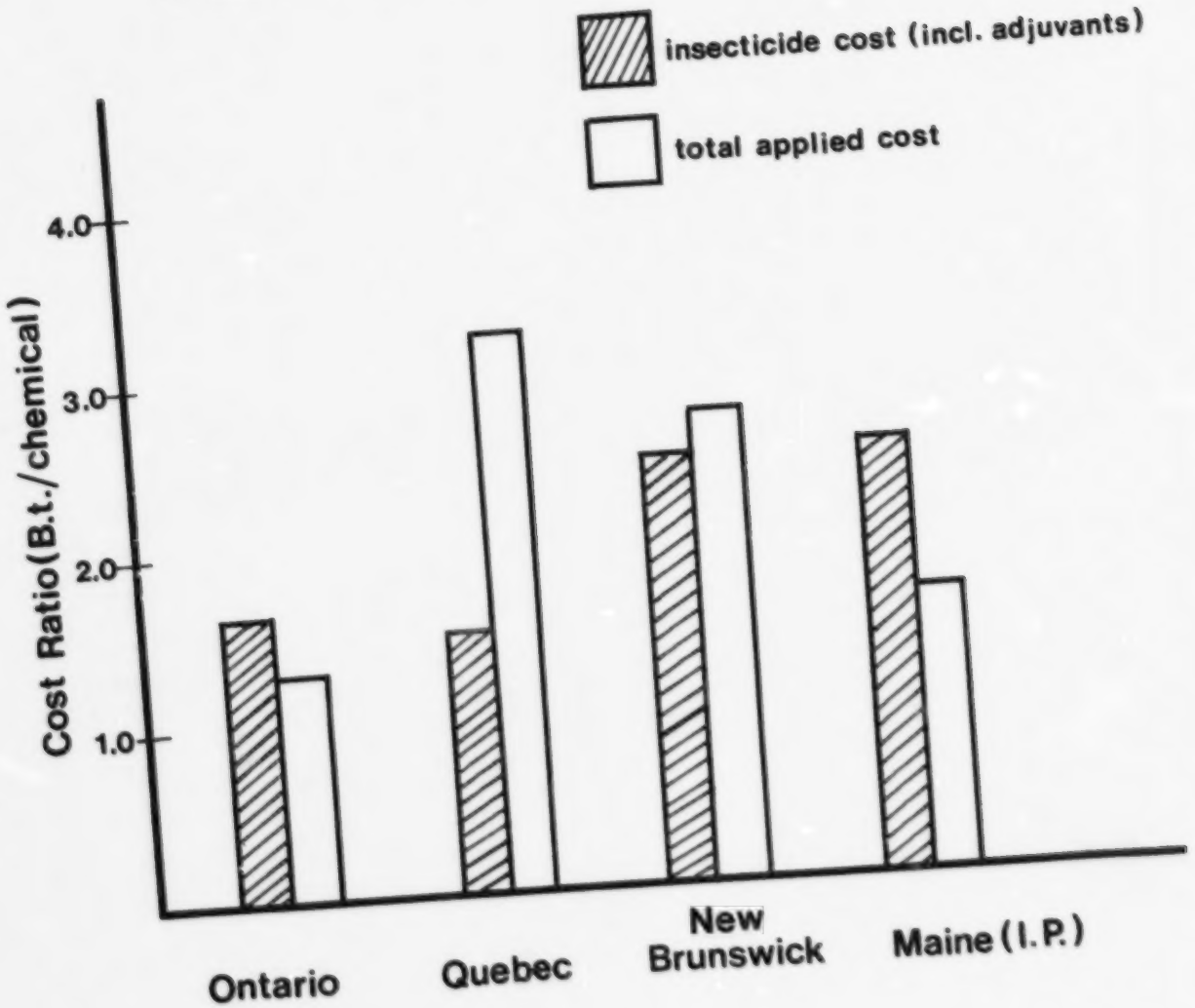
from 0.68 dollars in 1980 to 0.32 dollars in 83. This translates to reduced product cost per hectare - $13.18/ha. in 1980 to $6.96/ha. in 1983. However, coincident with this decline has been an increase in aerial application costs for all pesticides; consequently, the total cost of B.t. application per hectare has remained constant in the past four years ($27.13/ha. in 1980 vs. $26.73/ha. in 1983). At the same time, the cost of chemical insecticide use has increased steadily, due to increasing product cost and application costs.

Application costs are virtually impossible to compare from one jurisdiction to another, largely because each agency calculates costs differently. Some agencies (Ontario) include only aircraft, pilots, spray materials, while other such as New Brunswick and Nova Scotia include salaries, vehicles and other overhead charges along with direct application costs. Another factor which makes comparison difficult over time is that many agencies are now applying B.t. at 30 BIU/ha., which is 50% more than was generally applied (20 BIU/ha.) in 1980.

Perhaps the most significant comparison is the relative cost of B.t. application and chemical application within each jurisdiction, because this removes the inter-agency variability in how costs are calculated. Comparing the total cost of B.t. application to that for chemical application, B.t. is significantly more costly in New Brunswick (2.5 x) and Quebec (3.0 x) (Fig. 2). However, in the International Paper program (Maine) and in Ontario, B.t. cost is only 1.5 x more than chemical applications. Why there is such a difference in this ratio is difficult to determine, but it probably relates to how B.t. is handled and used within the context of the operation, e.g. whether B.t. is applied at much higher finished volume than chemical; type of aircraft used for B.t. vs. aircraft used for chemical, and size and distribution of B.t. blocks relative to chemical blocks.

Figure 2

Relative Cost of Chemical And B.t. Application, 1983

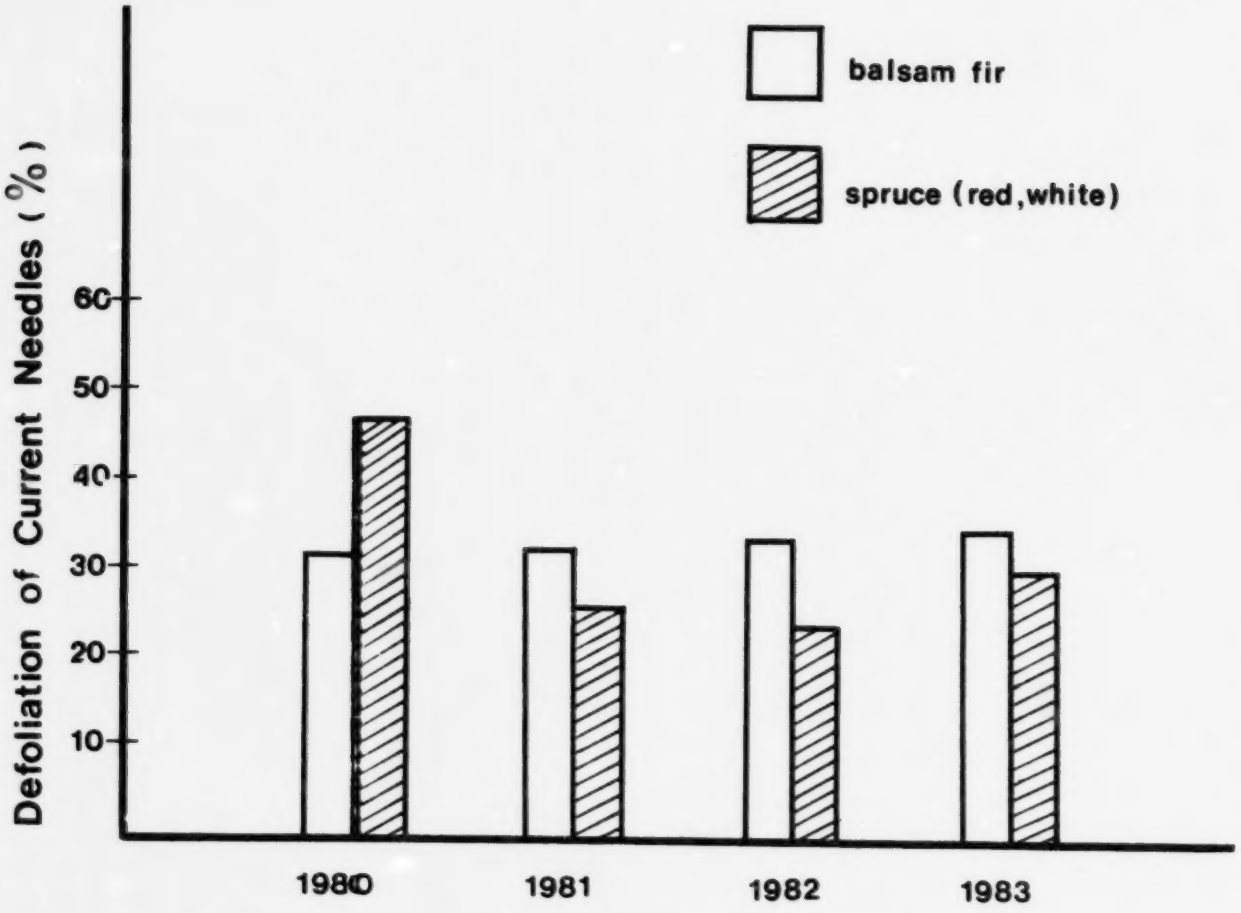


2. Effectiveness

Once upon a time, not long ago, the effectiveness of B.t. products was characterized generally as inconsistent, with some programs providing very good protection and others poor protection. In 1983, however, there is general agreement among users that B.t., particularly when applied at 30 BIU/ha. provides as good foliage protection on fir and spruce as chemical insecticides. A widely used protection objective is to limit defoliation to 50% or less of the current year's foliage, or conversely, to retain 50% or more of the current foliage. A review of results from 1980 to 1983 shows clearly that consistently satisfactory protection has been achieved on both spruce and fir. Figure 3 depicts the averages of all results reported for all agencies for each year. Defoliation of fir has been consistently limited to 30 to 35%, whereas on spruce, protection seems to have improved in recent years, with defoliation now limited to about 25%. One is tempted to speculate on why the performance of B.t. has apparently improved in recent years. Several factors have probably contributed to improvement: use of higher rates (30 BIU/ha.), improved products from the stand point of mixing and application (and possibly better quality control), and improved application technology. Regardless, it is reassuring to see that B.t. now appears to provide just as good foliage protection on spruce and fir as the commonly used chemical insecticides.

Figure 3

Defoliation of Spruce and Fir Protected with B.t.(averages of all reported results by year).



3. Operational Considerations

The use of B.t. in a large operational spray program has some clear advantages, but also generates some difficulties not experienced with chemicals. The potency of B.t. products (number of BIU per litre) has been, and continues to be variable, resulting in unrecognized differences in application rates. Because of the production process (fermentation), this will likely be very difficult to rectify. It appears however that variablility usually takes the form of exceeding the potency stated on the label; manufacturers insist that label claims for potency are guaranteed as a minimum.

Changes in product formulations and formulation characteristics from year to year make it difficult for operators to standardize spray delivery systems for aerial application. As well, there is still considerable uncertainty about the optimum droplet spectrum for B.t.

Most currently-used formulations require dilution with water for application. This diluted spray mix may deteriorate with time if, for some reason, application is delayed, e.g. unsatisfactory weather conditions. Monitoring of the potency, however indicates that mixed B.t. is reasonably stable for at least 72 hours.

B.t. formulations are typically dense, with the result that, in general, spray aircraft can carry fewer gallons of B.t. than chemical insecticide. This results in fewer acres sprayed per load, and increased application cost.

The development of highly concentrated formulations, some of which can be applied undiluted (neat), resolves some of the operational problems such as possible deterioration of diluted B.t. and the higher application cost associated with higher applied volumes. However, the concentrated formula-

tions present new problems in pumping and mixing (if necessary) due to the viscosity of the material.

Generally, B.t. should not be applied until budworm larvae are half grown and have started actively feeding. Because of this, B.t. cannot be applied as early as chemical insecticide, thus shortening the period available for spraying. This narrower "spray window" creates problems for the applicator in ensuring that sufficient aircraft are available to complete the program in the time available.

On the positive side, B.t. is a "safe" insecticide. The occupational health hazard for mixing site crew and pilots is minimum. Because B.t. is selective in its action, affecting only insects of the moth and butterfly family (Lepidoptera), it can be used in virtually all ecosystems with little or no damage to non-target organisms. To a large extent, this removes the need for environmental monitoring, which historically has been a costly program in New Brunswick. Again because of its selectivity, B.t. does not affect parasites and predators of the budworm, thus allowing them to exert their effect on budworm. As well, the above factors combine to make B.t. much more acceptable to the public than chemical insecticides.

The development of new formulations which can be applied neat removes the need for a mixing operation, thereby reducing staff and equipment costs.

4. Environmental Constraints

Provincial (State) regulatory agencies impose restrictions on aerial application of forest pesticides, including B.t. At one time, B.t. was noted for its inconsistency in effectiveness. That problem having been largely resolved, B.t. is now renowned for the inconsistency of environmental constraints imposed on its use by regulatory agencies. Restrictions on B.t. use in Maine are minimal, with no setbacks required around habitation, open water or municipal water supplies (Table 1). At the other extreme is Quebec; until 1983, there were no restrictions on B.t. use, but in 1983, Environment Quebec prevented the application of B.t . within one kilometre of habitation, farm lands and municipal water supplies. In some provinces, setbacks for B.t. are almost as restrictive as for chemicals, and in one province (Ontario) the setback requirement around water varies from one region to another. In summary, the setbacks imposed for B.t. use in some provinces appear to ignore the fact that B.t. is a much more benign material than chemicals. Such restrictions do little to assure the public that B.t. is a "safe" pesticide. As well, the excessive setbacks required in some jurisdictions effectively prevent <u>any</u> protection of significant portions of the productive forest.

Table 1. Summary of Setbacks Required by Environment Agencies for Aerial Spraying of B.t.

	Maine	Quebec	Ontario	Nova Scotia	New Brunswick
Human Habitation	none	1000 m.	-	150 m.	155 m.
Municipal water supply	none	1000 m.	-	1,500 m.	3,200 m.
Open water	none	-	60 m. (Some situations)	60 m.	65 m.
Cultivated Land	none	1000 m.	none	60 m.	none

POOR

QUALITY

ORIGINAL